SECOND FORMAL PROGRAM REVIEW BRIEFING FOR
MARSHALL SPACE FLIGHT CENTER

MISSION ROLES FOR THE SOLAR ELECTRIC PROPULSION STAGE WITH THE SPACE TRANSPORTATION SYSTEM

(NASA-CR-120664) MISSION ROLES FOR THE SOLAR ELECTRIC PROPULSION STAGE WITH THE SPACE TRANSPORTATION SYSTEM (Northrop Services, Inc., Huntsville, Ala.) 63 p HC $4.25 CSCL 21C G3/20
N75-29170
Unclas
31058

DECEMBER 3, 1974

NORTHROP SERVICES, INC.
CONTRACT NO. NAS8-30742

MISSION ROLES FOR SEPS WITH THE SPACE TRANSPORTATION SYSTEM

PRESENTATION TOPICS

- EXECUTIVE SUMMARY
- SELECTED OPERATIONAL CONSIDERATIONS AND MISSION CHARACTERISTICS
- TRADE STUDIES & TECHNOLOGY ASSESSMENTS INFLUENCING SEPS CONFIGURATION DEFINITION
- PROGRAM SUPPORT REQUIREMENTS
- DEVELOPMENT & OPERATIONS COST ESTIMATES

MISSION ROLES FOR SEPS WITH THE SPACE TRANSPORTATION SYSTEM

PRIMARY OBJECTIVES

- DEFINE ROLES CONTRIBUTING TO TRANSPORT COST EFFECTIVENESS
- PERFORM OPERATIONAL ANALYSES ON PAYLOAD TRANSFER & SERVICING FUNCTIONS
- DEVELOP CONCEPTUAL DESIGNS FOR PAYLOAD TRANSFER & SERVICING
- DEFINE SEPS INTERFACES WITH STS
- ASSESS DESIGN IMPACTS ON SEPS SUBSYSTEMS

STUDY SCOPE

6,500 MANHOURS

MISSION ROLES FOR SEPS WITH THE SPACE TRANSPORTATION SYSTEM

CONTRIBUTING SECONDARY OBJECTIVES

- QUANTIFY TRANSPORT COST EFFECTIVENESS OF SEPS RELATIVE TO A NASA MISSION MODEL
- DEFINE SYSTEM OPERATIONAL PROFILE WITH FLIGHT ASSIGNMENT AND DATES. IDENTIFY NEW ROLES.
- IDENTIFY OPERATIONAL REQUIREMENTS AND DEFINE SEPS PROGRAM SUPPORT REQUIREMENTS
- ESTABLISH SEPS TRANSPORT PERFORMANCE CAPABILITIES AND SHOW POTENTIAL IMPROVEMENT
- IDENTIFY BENEFITS TO IUS-TUG & PAYLOADS RESULTING FROM SEPS USE
- IDENTIFY PROBLEM AREAS FOR FUTURE INVESTIGATION
- DEVELOP OPERATIONAL COSTS OF SEPS

SEPS FUNCTIONS IN ACCOMPLISHING THE REFERENCE MISSION MODEL*
FROM 1981 TO 1991

- o SEPS - TUG GEOSYNCH & INTERMEDIATE ORBIT COMBINED MISSIONS COMPRISE 179 PAYLOADS ACCOMPLISHING 93% OF ALL GEOSYNCH MISSIONS, 39% OF INTERMEDIATE ORBIT MISSIONS

- o TUG ALONE ACCOMPLISHES 7% OF GEOSYNCH MISSIONS, AND 61% OF INTERMEDIATE ORBIT MISSIONS

- o 4 OF 16 PLANETARY MISSIONS USE SEPS (8 LAUNCHES)

- o LOW EARTH ORBIT SEPS MISSIONS ARE FEASIBLE BUT NO SPECIAL COST SAVINGS WERE IDENTIFIED

*REFERENCE MISSION MODEL TAKEN FROM NASA TMX-64751, REV 2 JANUARY 1974 "THE OCTOBER 1973 SPACE SHUTTLE TRAFFIC MODEL"

OPERATING CONSTRAINTS INFLUENCE ON STS FLIGHTS REQUIRED TO ACCOMPLISH MISSION MODEL

- GENERAL PURPOSE MISSION EQUIPMENT DESIGNS EVOLVED IN THIS STUDY MAKE ANY NUMBER OF PAYLOADS PER SORTIE FEASIBLE
- SEPS HIGH PERFORMANCE ESSENTIALLY REMOVES PAYLOAD WEIGHT PER SORTIE LIMITS
- AVAILABLE PAYLOAD VOLUME IN ORBITER CARGO BAY BECOMES THE SIGNIFICANT LIMITING FACTOR

COMPARISON OF STS FLIGHTS REQUIRED FOR MISSION MODEL VS ALLOWED PACKAGING SYSTEM

STS VARIANT/PACKAGING SYSTEM	TANDEM	SIDE BY SIDE	THREE DIMENSIONAL
BASELINE STS	497	488	488
STS WITH SEPS	489	467	461
STS FLIGHTS SAVED	8	21	27

NUMBER OF PAYLOADS FOR TUG OPERATING ALONE LIMITED TO THREE UP AND ONE DOWN ON EACH SORTIE.

STS CONFIGURATION TRADES

SHUTTLE FLIGHTS REQUIRED FOR MISSION MODEL

SEPS \ TUG	30' BL TUG	30' TUG (ΔRL-10)	25' TUG	21' & 25' TUGS	REUSABLE TRANSTAGE
NO SEPS	468	480*	468	-	-
BL SEPS 10 KHR THRUSTERS	458	459*	-	465	-
BL SEPS 20 KHR THRUSTERS	458	-	455	464	-
50 KW SEPS SPSA 20 KHR THRUSTERS	456	-	454	456	-
50 KW SEPS Isp=4160 SPSA 20 KHR THRUSTERS	455	-	454	458	-
100 KW SEPS SPSA 20 KHR THRUSTERS	-	-	-	-	477**

- o 90 DAY TRIP TIME LIMIT FOR SEPS
- o ELLIPTICAL CHANGEOVER ORBITS, PERIGEE ALT. NOT CONSTRAINED
- o RADIATION EFFECTS INCLUDED
- o SEPS CONFIGS. WITH 20 KHR THRUSTERS REFUELED 3 TIMES
- o INTERMEDIATE ORBIT PAYLOADS NOT DELIVERED ON SEPS FLIGHTS

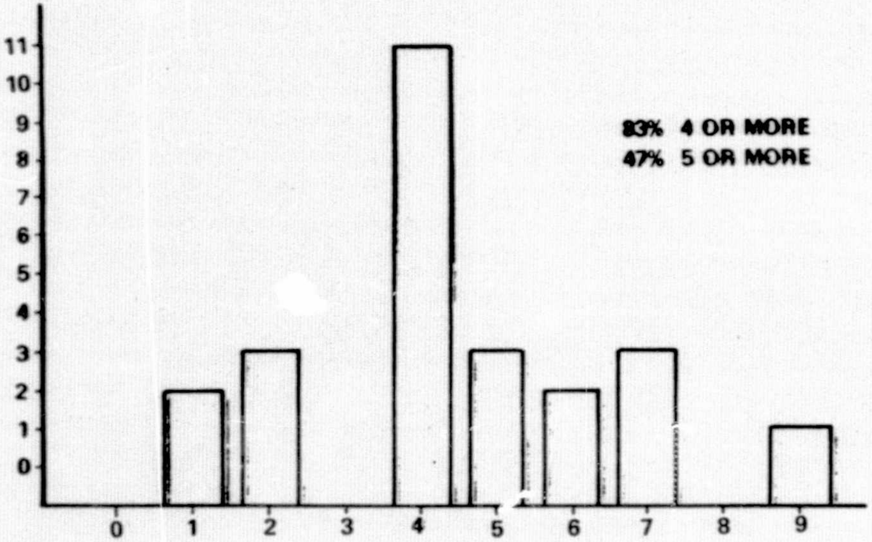
* PLD PL-23 JUP-SAT ORBITER-LANDER COULDN'T BE DELIVERED

** REQUIRES TANDEM TRANSTAGES + KICKSTAGE FOR SOME PLANETARY PLDS

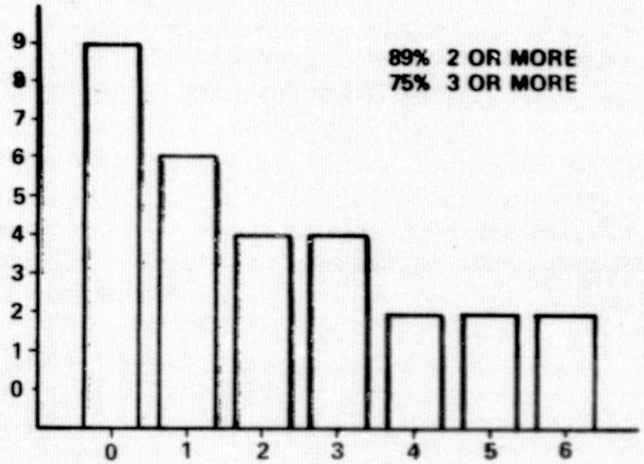
STS OPERATIONAL TRADES

30' BL TUG WITH BL SEPS (20 KHR THRUSTERS)

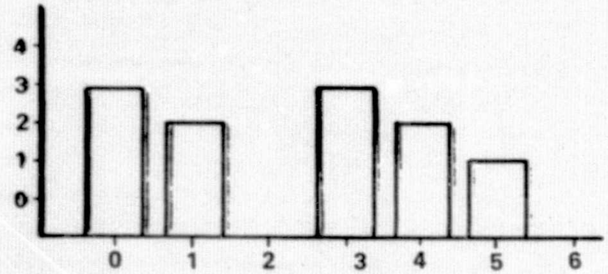
REFUELED	INTER-ORBS	CHANGE-OVER ORBITS	TRIP TIME LIMIT-DAYS	1ST SEPS LAUNCHED	RTS IN '81 THRU '83	SHUTTLE FLIGHTS REQD
3X	YES	ELLIPTICAL $r_p \geq 20000$ km RAD. IGNORED	90	1981	NO	451
3X	YES	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1981	NO	452
3X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	180	1981	NO	456
3X	NO	ELLIPTICAL $r_p \geq 20000$ km RAD. IGNORED	90	1981	NO	457
3X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1981	NO	458
3X	NO	CIRCULAR $r \geq 20000$ km RAD. IGNORED	90	1981	NO	460
4X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1981	NO	457
3X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1984	NO	457
3X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1981	YES	472



HISTOGRAM – NUMBERS OF PAYLOADS SHUTTLE IN UP MANIFESTS

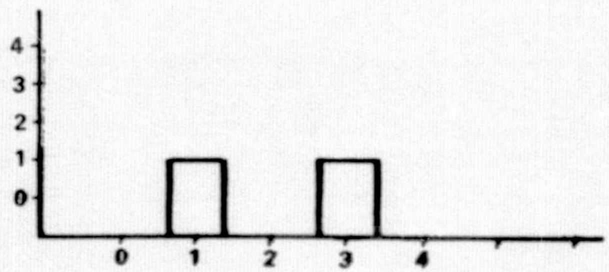


HISTOGRAM – NUMBERS OF PAYLOADS IN SHUTTLE DOWN MANIFESTS



HISTOGRAM – SHUTTLE DOWN PAYLOADS IN COMBINATION WITH FOUR UP

HISTOGRAM – DOWN PAYLOADS IN COMBINATION WITH FIVE UP

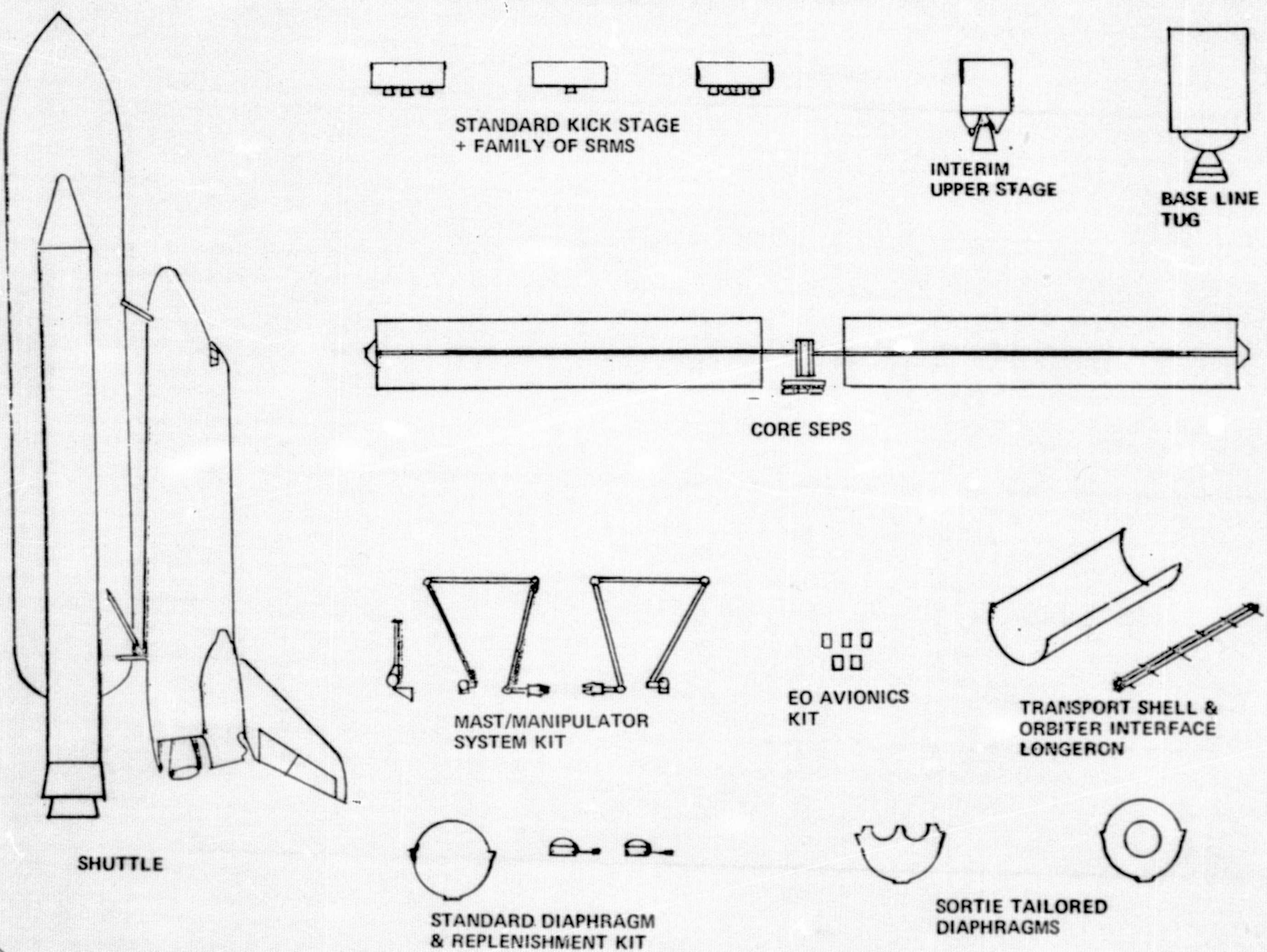


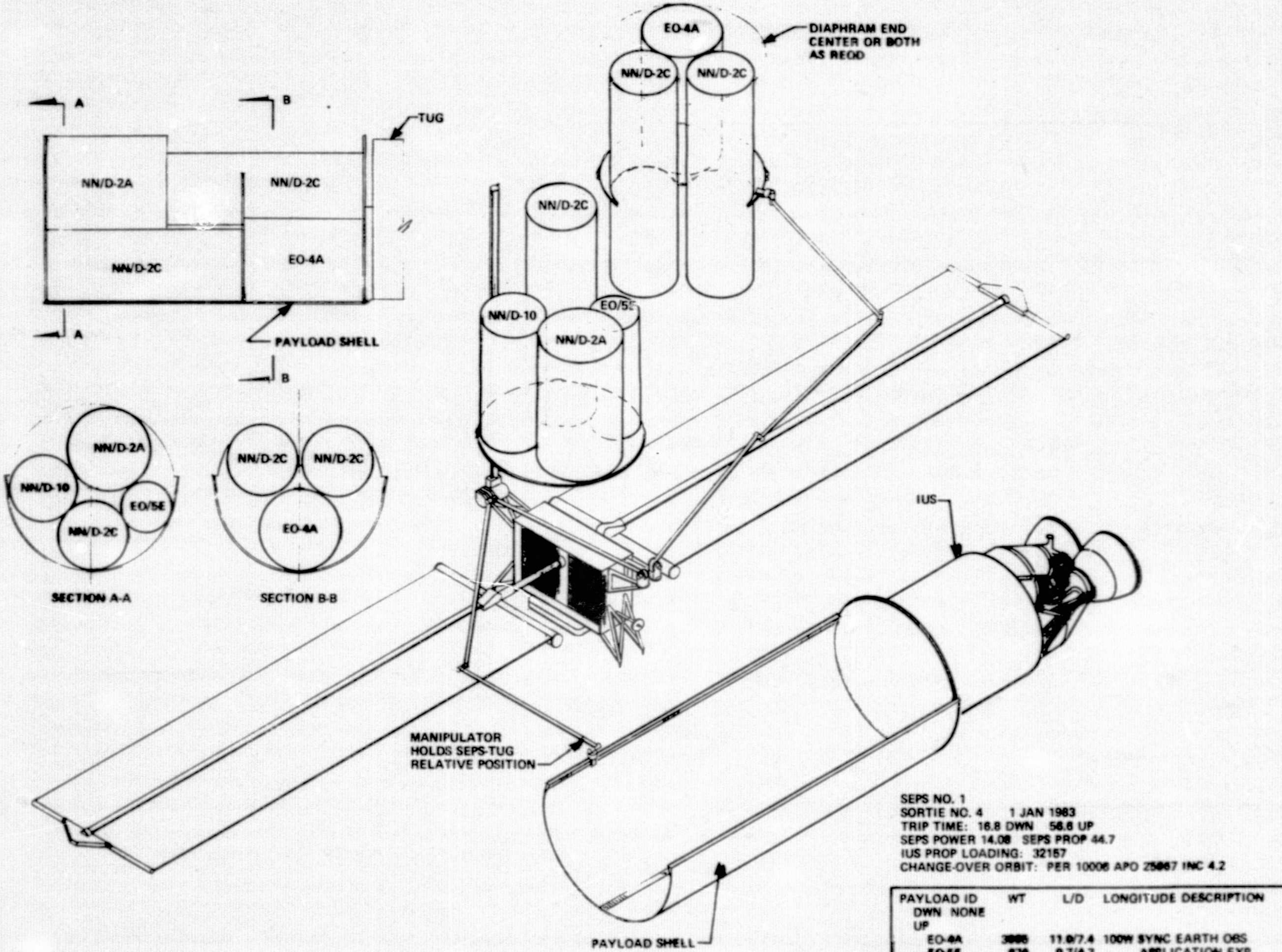
HISTOGRAM – DOWN PAYLOADS IN COMBINATION WITH SIX UP

DECISION CONTROLLING FACTORS FOR SEPS CONFIGURATION

- TRANSPORTATION EFFICIENCY DEPENDS ON MULTIPLE PAYLOAD DELIVERIES AND RETRIEVAL
- COST EFFECTIVENESS REQUIRES GPME WITH FEW SPECIAL ITEMS
- GPME MUST SIMPLIFY SHUTTLE-TUG OPERATIONS
- MULTIPLE PAYLOAD TRANSPORT & SERVICING MUST PLACE MINIMUM CONSTRAINTS ON PAYLOAD DESIGNERS
- SEPS SPACE STAY TIME LIMITED ONLY BY WEAR OUT - EXPENDABLES ARE EASILY REPLENISHED
- GPME WEIGHT INCREASE TO SIMPLIFY OPERATIONS RESULTS ONLY IN MODEST TRIP TIME INCREASES
- EO SEPS HAS NO ΔV LIMIT WITHIN MISSION MODEL REQUIREMENTS
- SIGNIFICANT PENALTIES OCCUR FOR OPERATION THROUGH VAN ALLEN BELTS

SPACE TRANSPORTATION SYSTEM ELEMENTS WITH SEPS

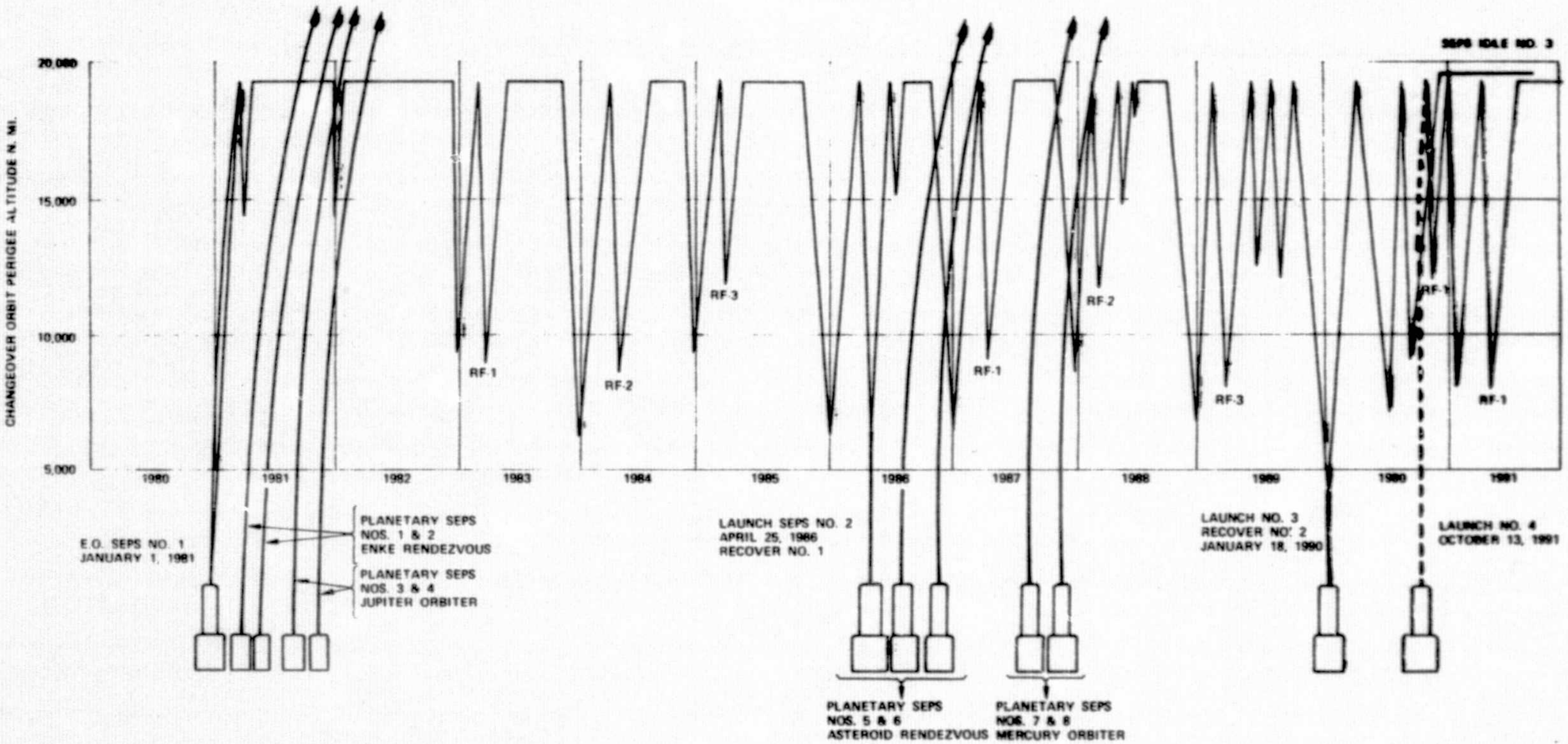




SEPS NO. 1
SORTIE NO. 4 1 JAN 1983
TRIP TIME: 16.8 DWN 56.6 UP
SEPS POWER 14.08 SEPS PROP 44.7
IUS PROP LOADING: 32157
CHANGE-OVER ORBIT: PER 10006 APO 25867 INC 4.2

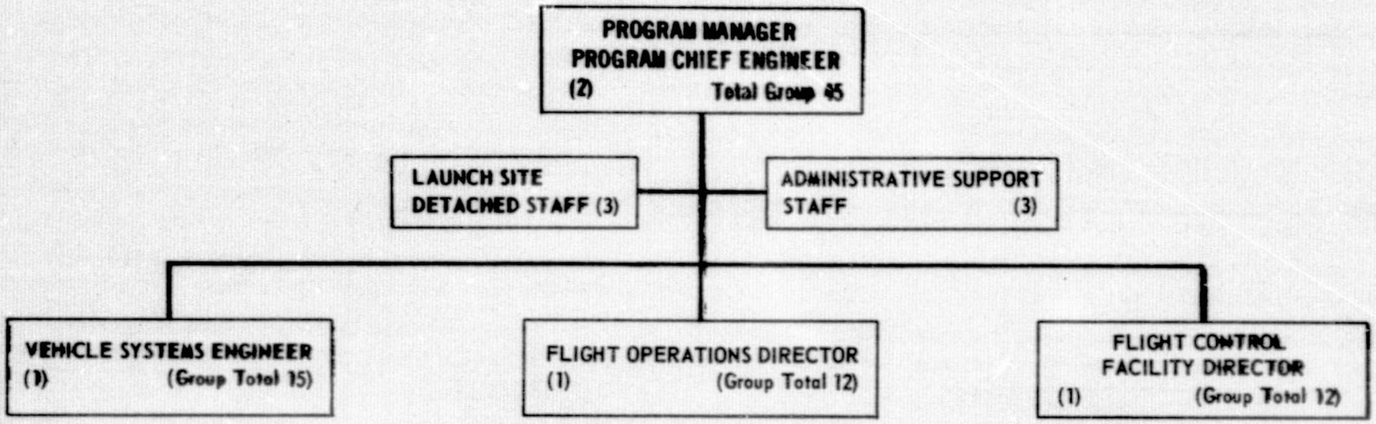
PAYLOAD ID	WT	L/D	LONGITUDE	DESCRIPTION
DWN NONE				
UP				
EO-4A	[illegible]	11.0/7.4	100W	SYNC EARTH OBS
EO-5E	879	9.7/4.7	–	APPLICATION EXP.
NN/D-2C	974	17.9/6.3	N/A	US DOM SAT C
NN/D-2C	974	17.9/6.3	N/A	US DOM SAT C
NN/D-2C	974	17.9/6.3	N/A	US DOM SAT C
NN/D-2A	1057	11.1/7.6	N/A	US DOM SAT A
NN/D-10	807	10.3/6.0	140E	GEOSYNC OPER MET SAT

SYSTEM OPERATIONAL PROFILE (30 FOOT BASELINE
TUG + 25,000 SEPS WITH 20,000 THRUSTER LIFE - REFUELED



SHUTTLE	15	19	22	28	27	35	34	32	32	30	32	34
SHUTTLE/TUG	0	6	2	8	11	11	10	8	4	[illegible]	9	8
SHUTTLE/ TUG/SEPS	0	2	1	2	2	2	3	2	4	4	5	2
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991

NO. OF SHUTTLE FLIGHTS	340
NO. OF SHUTTLE/TUG FLIGHTS	83
NO. OF SHUTTLE/TUG/SEPS FLIGHTS	29
TOTAL STS FLIGHTS	452



FUNCTIONS

- SUSTAINING ENGINEERING AND MAINTENANCE DIRECTION FOR SEPS AND ASSOCIATED GSE
- FLIGHT OPERATIONS CONTROL OF SEPS SUBSYSTEMS
- SUSTAINING ENGINEERING AND MAINTENANCE DIRECTION FOR CONTROL CENTER CONSOLES
- SOFTWARE DEFINITION/GENERATION FOR CHECKOUT, MONITORING, AND OPERATION OF SEPS SUBSYSTEMS
- LAUNCH PREPARATION & LAUNCH SUPPORT

STAFFING

- PROPULSION AND MECHANICAL SYSTEMS ENGR (4)
- AVIONICS SYSTEMS ENGINEER (4)
- PAYLOAD TRANSPORT/SERVICING SYSTEMS ENGR (5)
(THESE MEN ARE ALSO THE SEPS PILOTS FOR RENDEZVOUS AND MANIPULATION OPERATIONS)

FUNCTIONS

- MISSION PLANNING AND SIMULATION
- REAL TIME MISSION SUPPORT
- NEW SOFTWARE DEVELOPMENT AND MAINTENANCE

STAFFING

- FLIGHT DYNAMICS ENGINEER (6)
- SOFTWARE MANAGER (5)

FUNCTIONS

- DATA SYSTEM MANAGEMENT
- COMPUTER OPERATIONS MANAGEMENT (PRINCIPALLY COORDINATION OF PRIORITIES AND SCHEDULE WITH A NONDEDICATED COMPUTER COMPLEX)
- DATA TRANSMISSION LINE MANAGEMENT
- CONTROL CENTER MAINTENANCE

STAFFING

- FLIGHT SUPPORT DIRECTOR (2)
- DATA SYSTEM MANAGER (6)
- CONTROL CENTER MAINTENANCE (3)

ENTIRE GROUP SUPPORTS A RENDEZVOUS AND PAYLOAD TRANSFER OPERATION. FCC STAFFING DURING THIS PERIOD IS 16.

SEPS SUMMARY COSTS

NON-RECURRING	$ 122.5 M
PRODUCTION	137.9
OPERATIONS	33.8
TOTAL SEPS COSTS	$ 294.2 M

TRANSPORTATION COST EFFECTIVENESS COMPARISON

FLIGHTS REQUIRING UPPER STAGES

COST ELEMENT (DOLLARS IN MILLIONS)	BLSTS	BLSTS + BLSEPS (20 KHR-REFUELED)
SHUTTLE FLIGHTS @ $11.09	1508.	1353.
IUS EXPENDED @ $5.17	103.	98.
IUS WITH KICK STAGE @ $6.37	13.	13.
TUG RECOVERED FLTS @ $.96	87.	75.
TUG RECOVERED EXPENDED KS @ $2.16	15.	15.
TUG EXPENDED @ $14.16	0.	0.
TUG AND KS EXPENDED @ $15.36	92.	92.
SEPS SORTIES @ $.89	--	26.
VEHICLE INVENTORY COST SEPS @ (VARIES WITH PRODUCTION)	105.	138.
TOTAL	1923.	1810.
$ SAVED IN TRANSPORT COST	--	113.
SEPS DEVELOPMENT, OPERATIONS, START-UP, & REFURB. COST	102.	131.
TOTAL SYSTEM COST	2025.	1941.
NET $ SAVED	--	84.

EVALUATION CRITERIA FOR CHOICE OF SEPS CONFIGURATION

PROBLEM!!! EVALUATE AGAINST:

A. MINIMUM TO MEET ABSOLUTE MISSION NEED?

OR

B. COST EFFECTIVENESS ONLY AGAINST A REFERENCE MISSION MODEL ESTABLISHED FOR AN STS WITHOUT SEPS

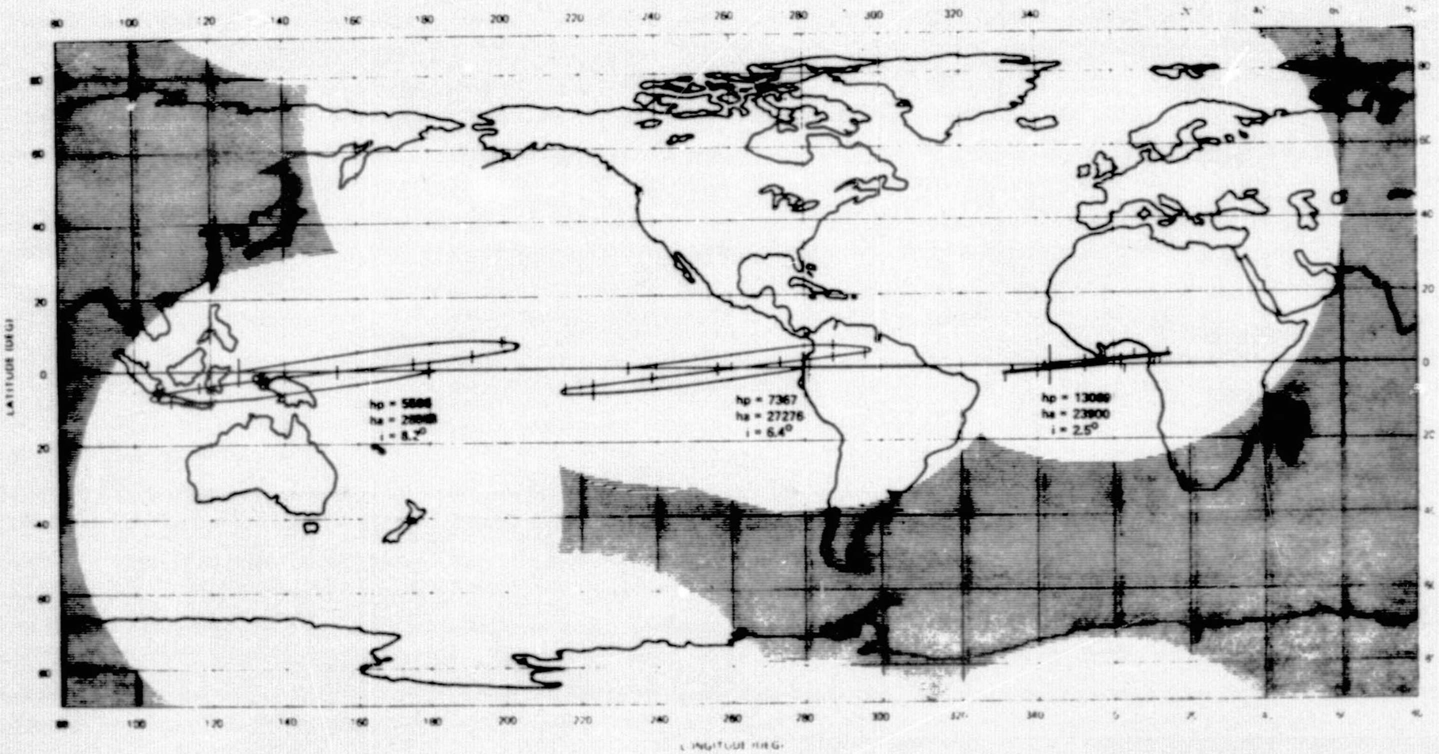
AND/OR

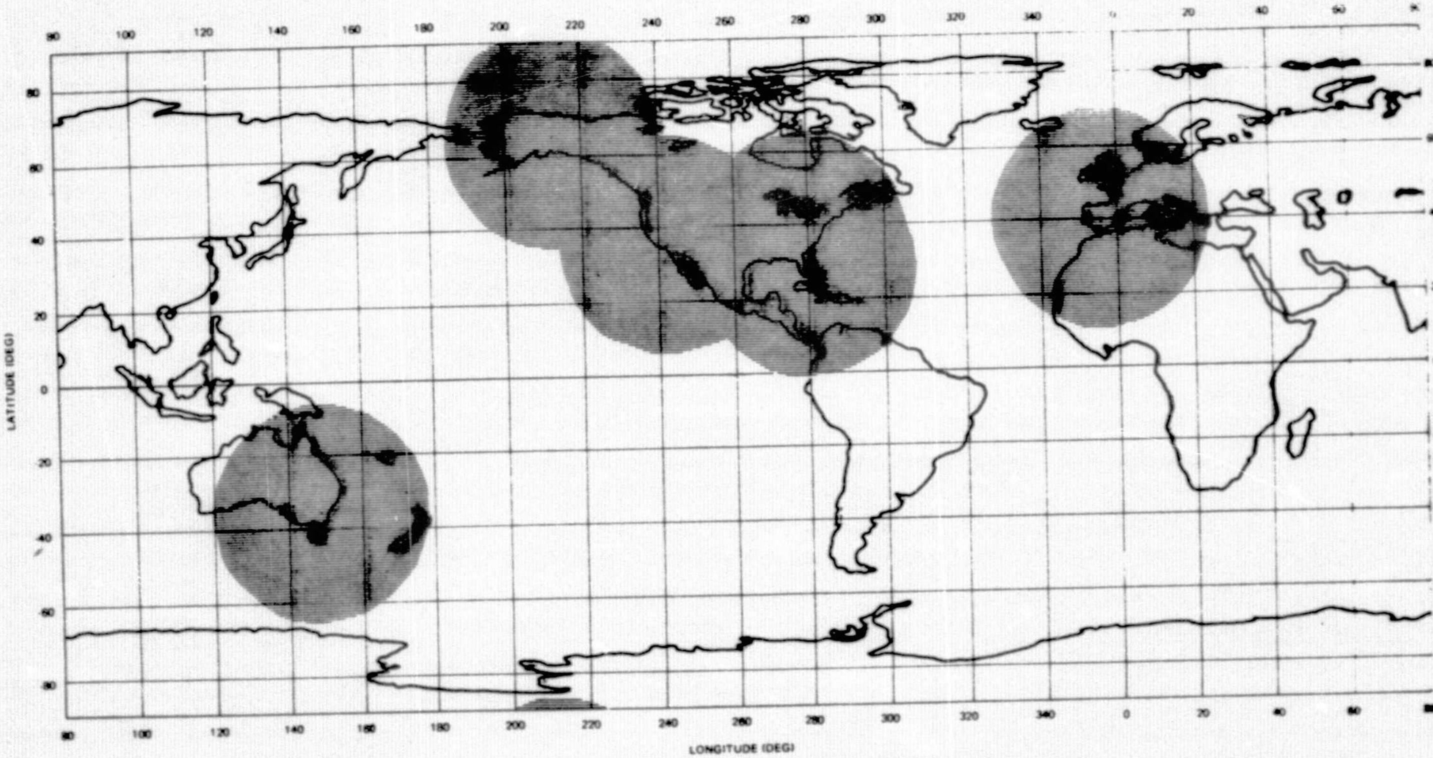
C. RECOGNIZABLE POTENTIAL VALUE OF FUNCTIONAL CAPABILITIES AND MISSIONS NOT IN PRESENT MISSION MODELS PLUS B FACTORS

CONCLUSIONS AND RECOMMENDATIONS

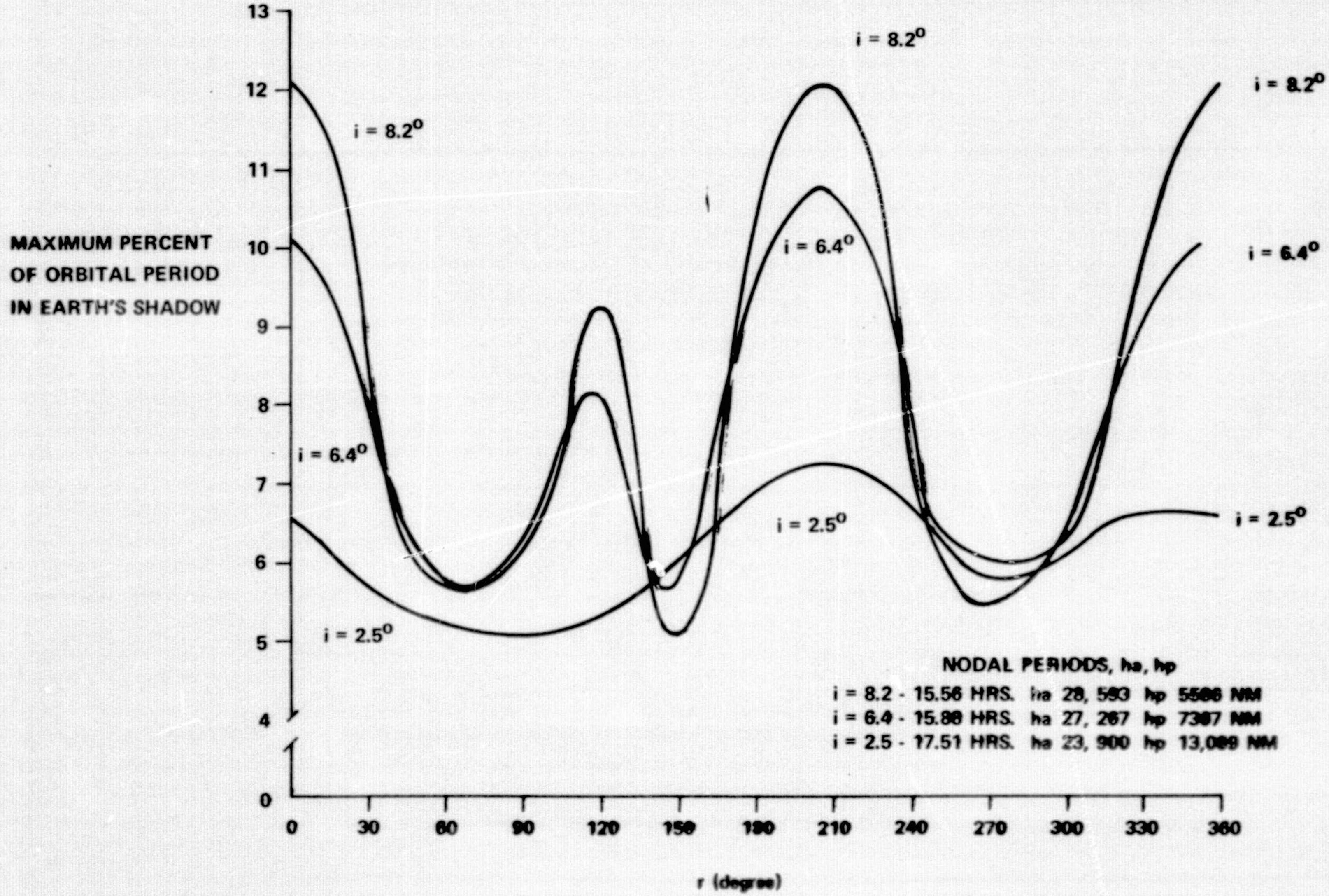
- USE OF SEPS WITH THE STS ADDS SIGNIFICANTLY TO CAPABILITY AND RESULTS IN SIGNIFICANT RETURN ON E.O. INVESTMENT
- THE MANIPULATOR/MAST SYSTEM WILL RESULT IN LOW OPERATIONAL COST AND MINIMUM IMPACT ON PAYLOADS. A MANIPULATOR SYSTEM IS RECOMMENDED FOR BASELINE SEPS
- SCREEN POWER DIRECT FROM THE SOLAR ARRAYS WITH INHERENT Isp OPTION IS RECOMMENDED
- SEPS DEVELOPMENT AND OPERATIONS COSTS ARE ONLY SLIGHTLY INFLUENCED BY POWER LEVEL
- HIGHER POWER SEPS ENHANCES TRANSPORTATION CAPABILITY

STDN COVERAGE FOR 5586 NAUTICAL MILE ORBITAL ALTITUDES

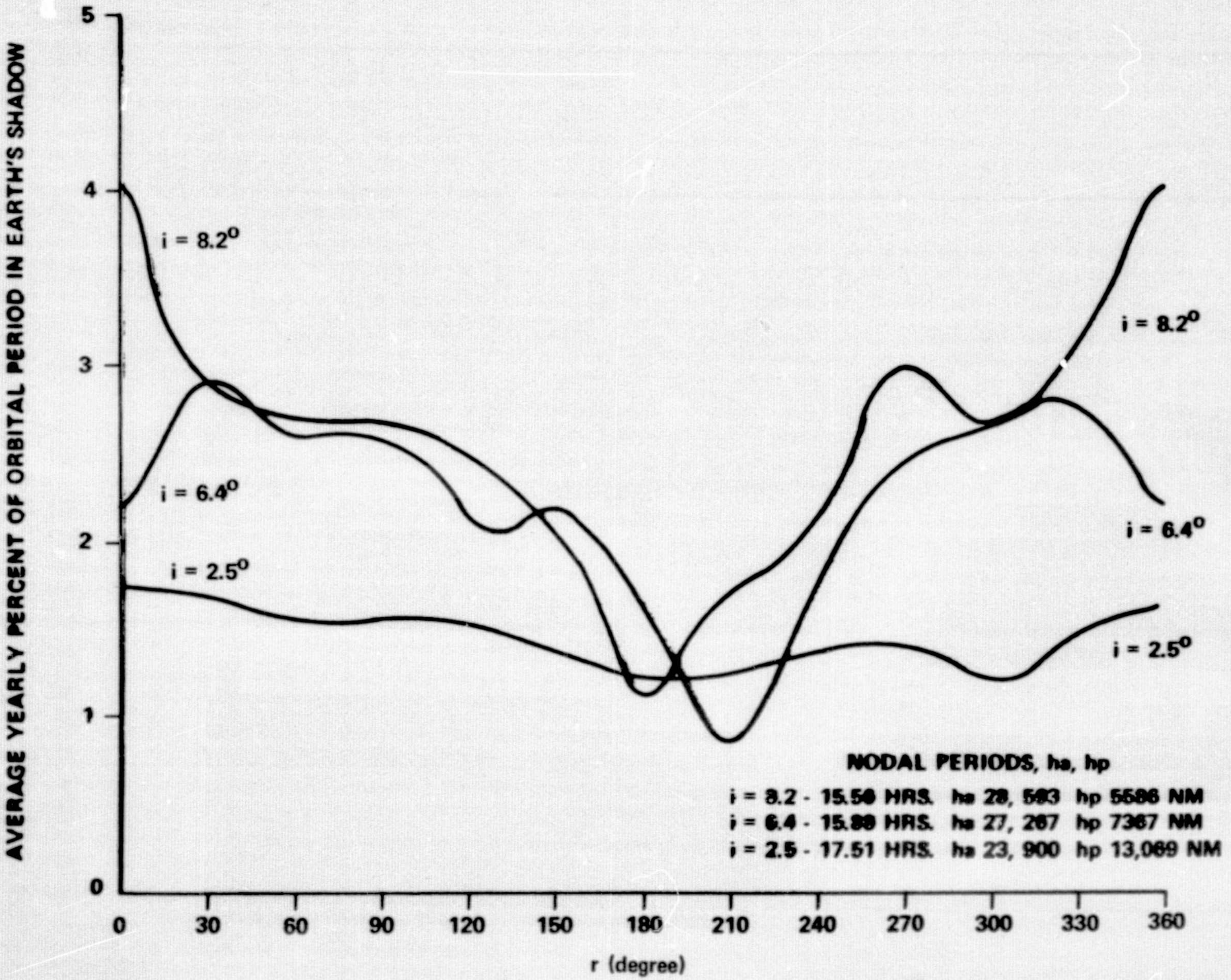




STDN COVERAGE FOR ORBITAL ALTITUDE [illegible] NM



MAXIMUM PERCENT
OF ORBITAL PERIOD
IN EARTH'S SHADOW
i = 8.2°
i = 8.2°
i = 8.2°
i = 6.4°
i = 6.4°
i = 6.4°
i = 2.5°
i = 2.5°
i = 2.5°
NODAL PERIODS, ha, hp
i = 8.2 - 15.56 HRS. ha 28, 593 hp 5586 NM
i = 6.4 - 15.88 HRS. ha 27, 267 hp 7387 NM
i = 2.5 - 17.51 HRS. ha 23, 900 hp 13,089 NM
0
4
5
6
7
8
9
10
11
12
13
0
30
60
90
120
150
180
210
240
270
300
330
360
r (degree)


AVERAGE YEARLY PERCENT OF ORBITAL PERIOD IN EARTH'S SHADOW
5
4
3
2
1
0
i = 8.2°
i = 6.4°
i = 2.5°
i = 8.2°
i = 6.4°
i = 2.5°
NODAL PERIODS, ha, hp
i = 8.2 - 15.56 HRS. ha 28, 583 hp 5586 NM
i = 6.4 - 15.88 HRS. ha 27, 267 hp 7367 NM
i = 2.5 - 17.51 HRS. ha 23, 900 hp 13,069 NM
0
30
60
90
120
150
180
210
240
270
300
330
360
r (degree)

BASIC DIFFERENCES
SHUTTLE-TUG ASCENT
TO GEOSYNCH VERSUS ASCENT
TO SEPS-TUG CHANGEOVER ORBIT

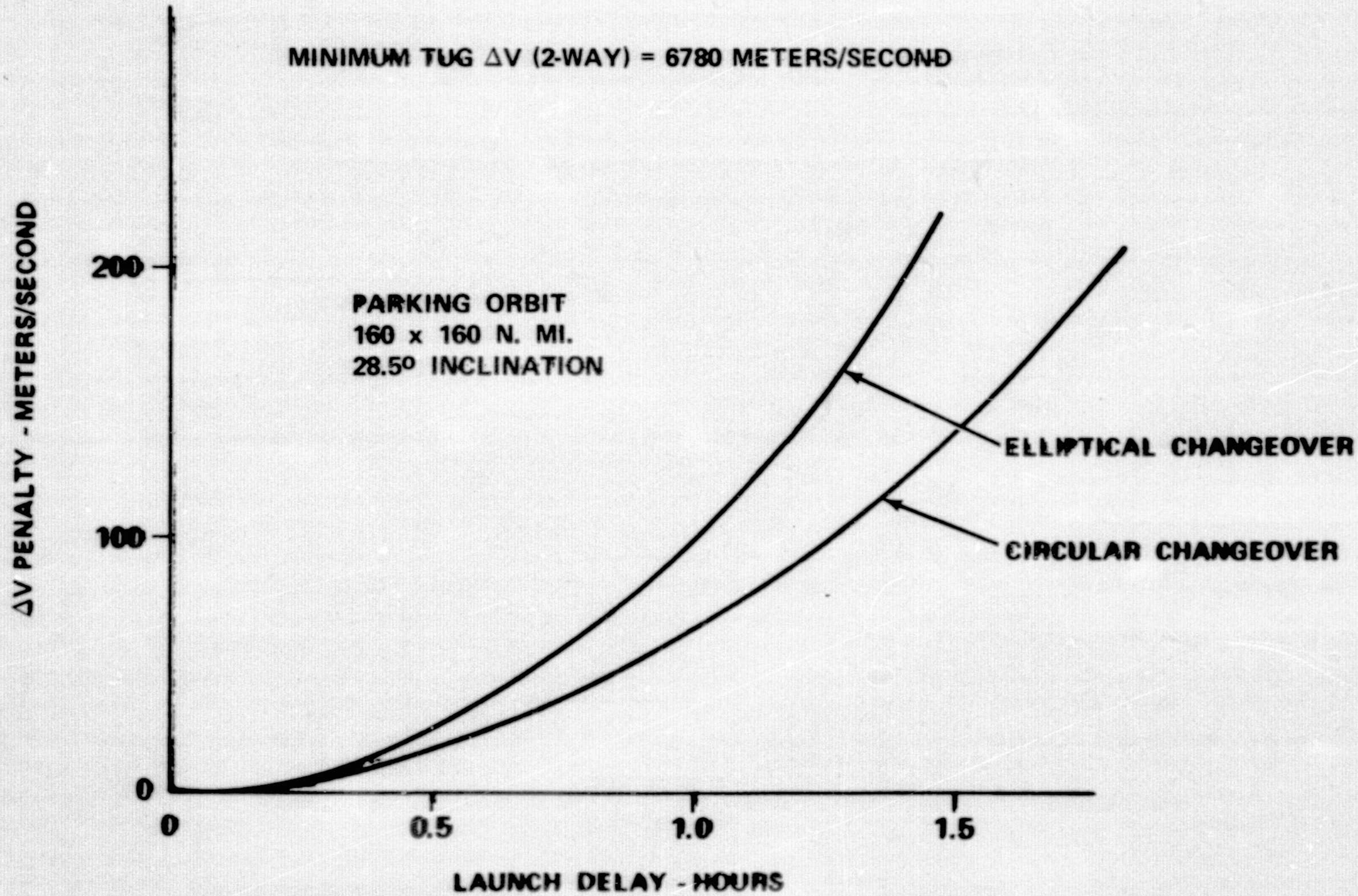
FOR TUG ONLY

- SHUTTLE LAUNCH FROM KSC MAY OCCUR AT ANY TIME. TUG WAITS IN PARKING/PHASING ORBITS UNTIL EARTH ROTATES TARGET LONGITUDE TO PROPER RELATIVE POSITION.
- MAX WAIT TIME IN ORBIT ≈ 12 HOURS.
- TARGET LONGITUDE DICTATES WAIT TIME IN LOW ORBIT.
- TUG DESCENT BURN WAIT TIME $\leq$ 12 HOURS.

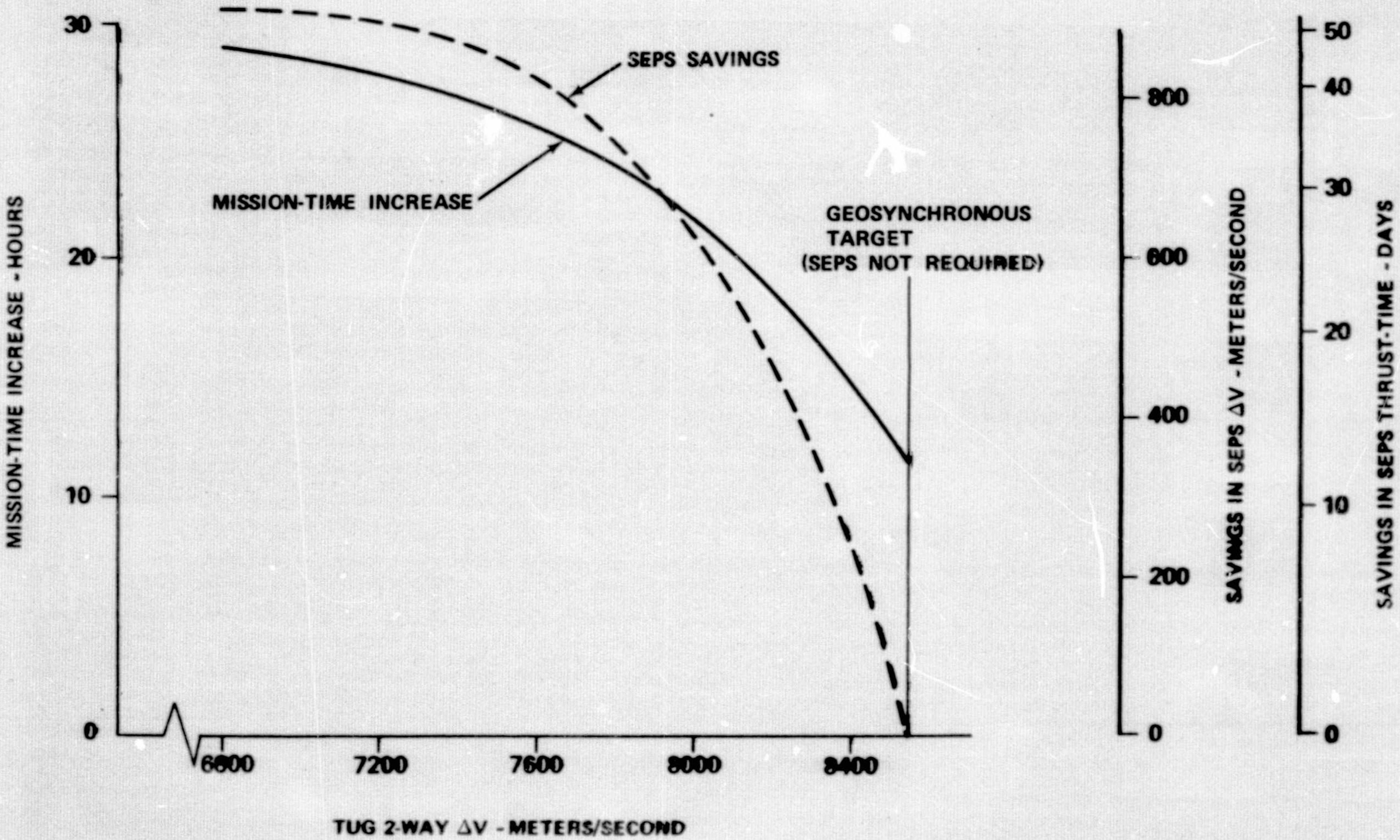
FOR TUG + SEPS

- SHUTTLE LAUNCH WINDOW ONCE PER DAY AT TIME DETERMINED BY SEPS ORBIT.
- FOR CIRCULAR SEPS ORBIT, TUG INITIATES ASCENT BURN ANYTIME PHASING IS PROPER.
- FOR ELLIPTICAL ORBITS, TUG MINIMUM ENERGY ASCENT/DESCENT WINDOWS EXIST ONCE PER SEPS ORBIT.

LAUNCH-DELAY PENALTIES FOR INCLINED CHANGEOVER ORBITS

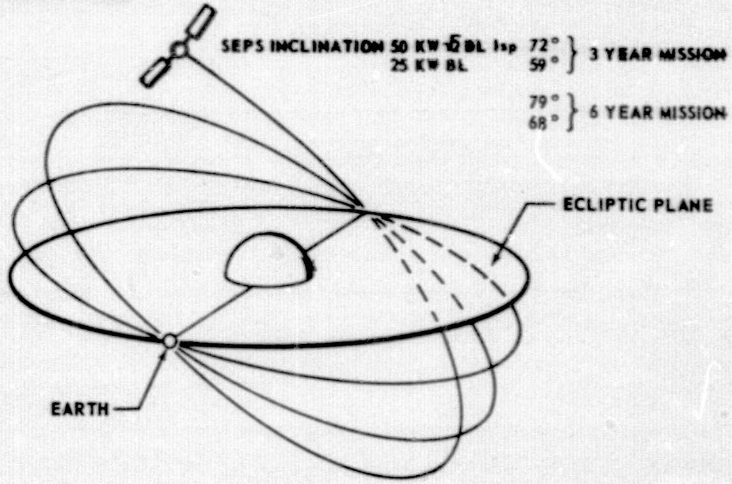


MISSION-TIME INCREASE AND SEPS SAVINGS (WITH ELLIPTICAL CHANGEOVER ORBITS)



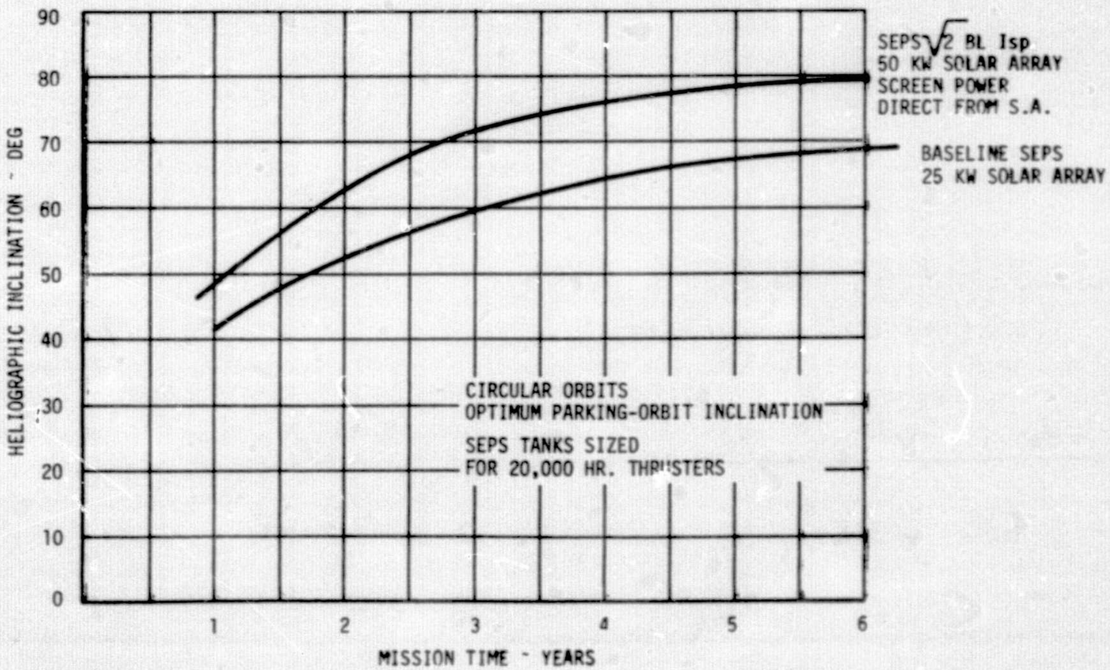
OUT OF ECLIPTIC MISSION

ADVANTAGES OF HIGHER POWER & Isp



	25 KW BASELINE	50 KW $\sqrt{2}$ BL Isp
SEPS		
INERT MASS	1373 KG	1713 KG
PROPELLANT	2289 KG	2240 KG
BURN TIME	18955 HOURS	15534 HOURS
COAST TIME	7324 HOURS	10746 HOURS
CENTAUR		
INERT MASS	1859 KG	1859 KG
PROPELLANT	7722 KG	7431 KG
BURN TIME	258.90 SEC	249.15 SEC

NOTE: SUN'S EQUATORIAL PLANE INCLINED 7 DEGREES TO ECLIPTIC AND ORIENTED SO AS TO ADD DIRECTLY TO INCLINATION WITH RESPECT TO THE ECLIPTIC PLANE.

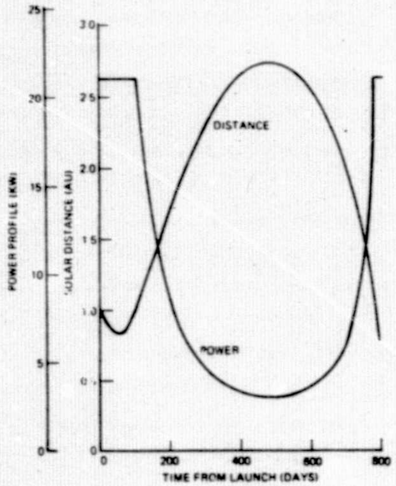


DESIRABLE CHARACTERISTICS FOR PLANETARY MISSION FLEXIBILITY

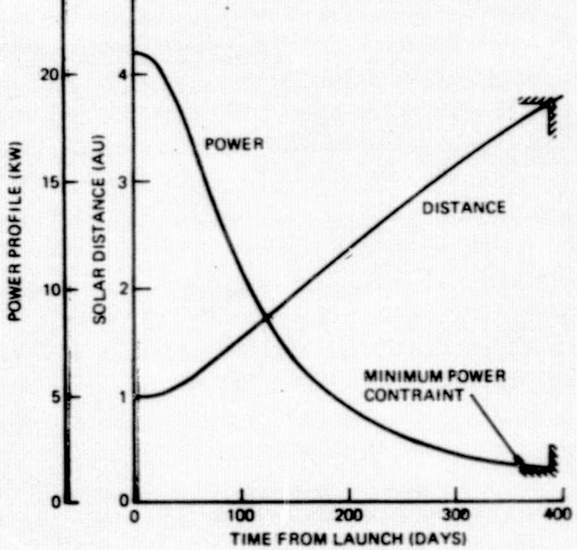
- IMPROVED AVERAGE T/W RATIO
  - INCREASED SOLAR ARRAY AREA & HIGHER KW/KG
  - IMPROVED POWER PROCESSOR EFFICIENCY AND/OR SCREEN POWER DIRECT FROM ARRAY
  - FULLER UTILIZATION OF THRUSTERS INHERENT CAPABILITIES
- OPTION TO OPERATE AT HIGH OR LOW Isp TO MATCH MISSION REQUIREMENTS
- RESERVE POWER TO SUPPORT PAYLOADS AT EXTRUDED DISTANCES

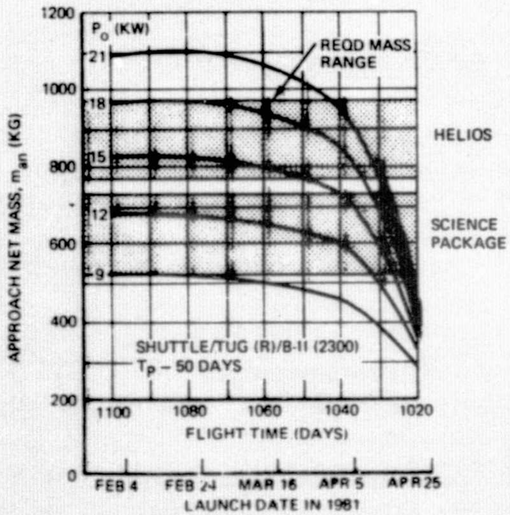
REVIEW OF TYPICAL PLANETARY MISSIONS FOR SEPS

1981 ENCKE RENDEZVOUS

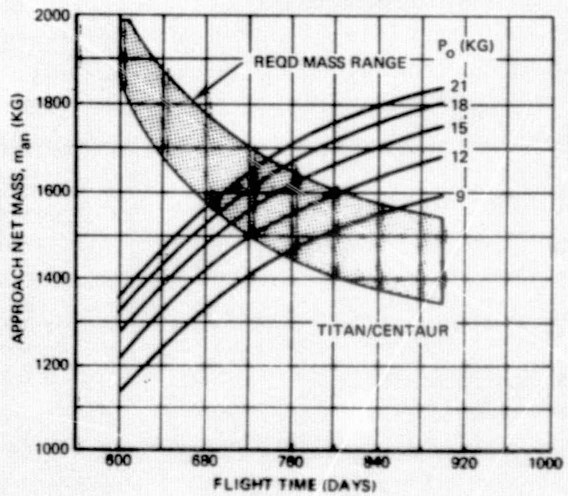


1981 JUPITER ORBITER





PL–26(2) 1981

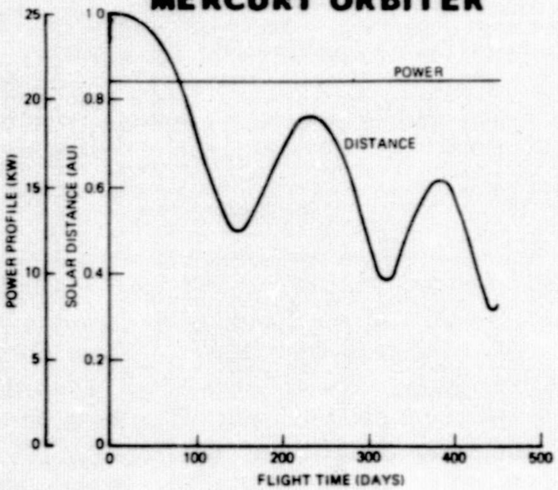


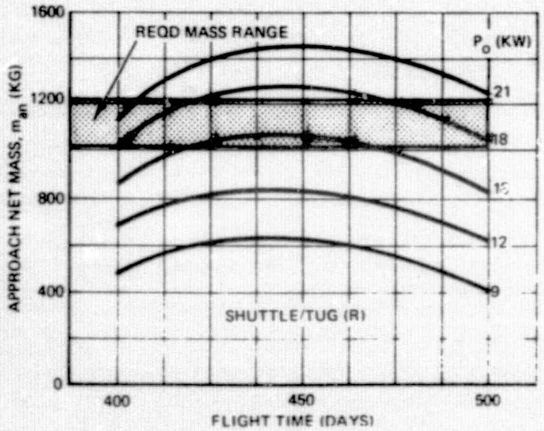
PL–19(2) 1981

REVIEW OF TYPICAL PLANETARY MISSIONS FOR SEPS

(CONTINUED)

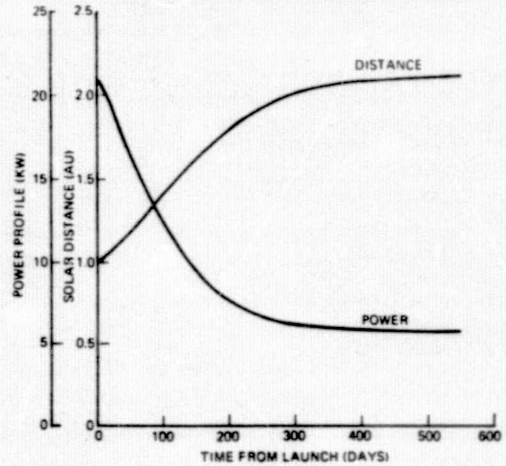
MERCURY ORBITER

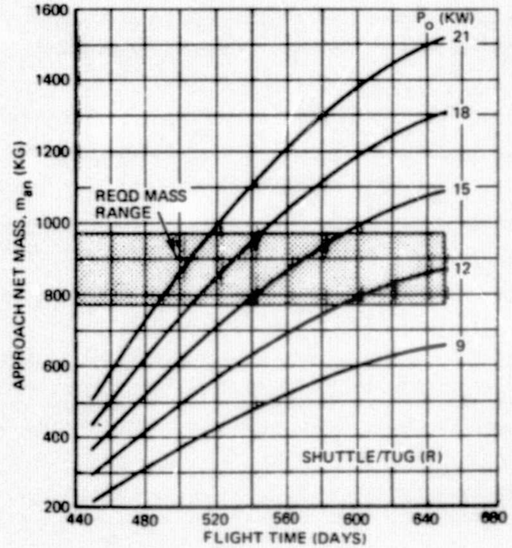




PL-13(2) 1987

METIS RENDEZVOUS

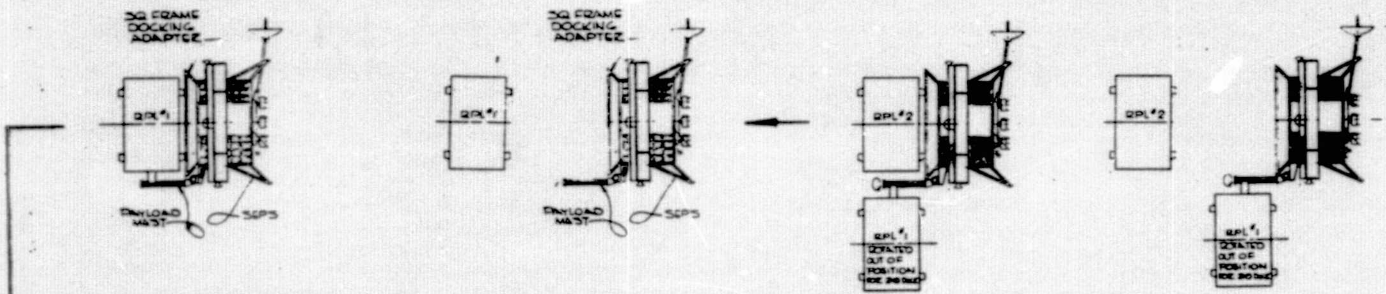




PL-28(2) 1986

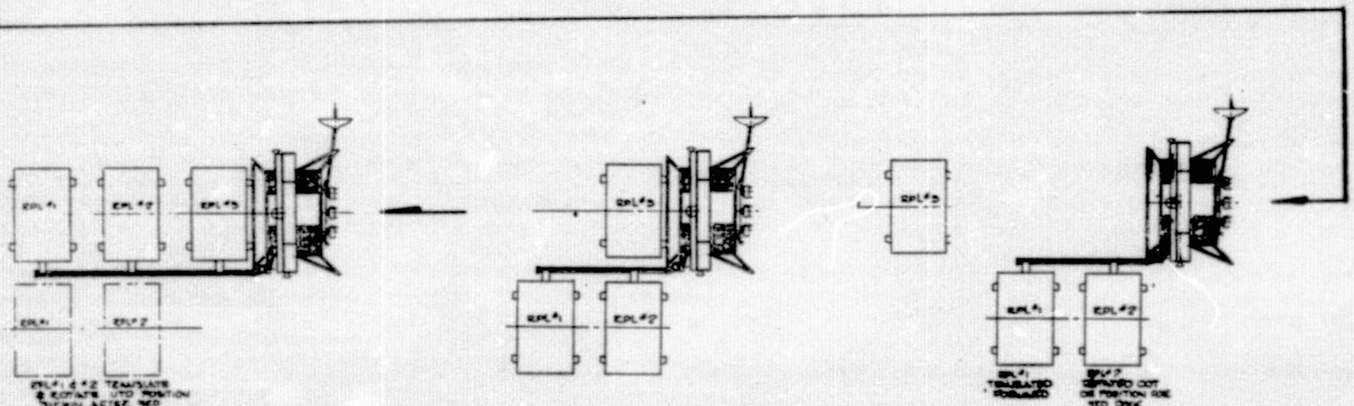
TRADE STUDIES AND TECHNOLOGY ASSESSMENTS

- PAYLOAD TRANSFER AND SERVICING SUBSYSTEM
- RENDEZVOUS N&G AND SENSORS
- TSS TECHNOLOGY ASSESSMENT



DOCK & ATTACH PAYLOAD TO EXTENDABLE MAST BY DRIVING ARTICULATED LEGS TO TRANSLATE DOCKING FRAME TOWARD MAST CRUISE TO NEXT PAYLOAD

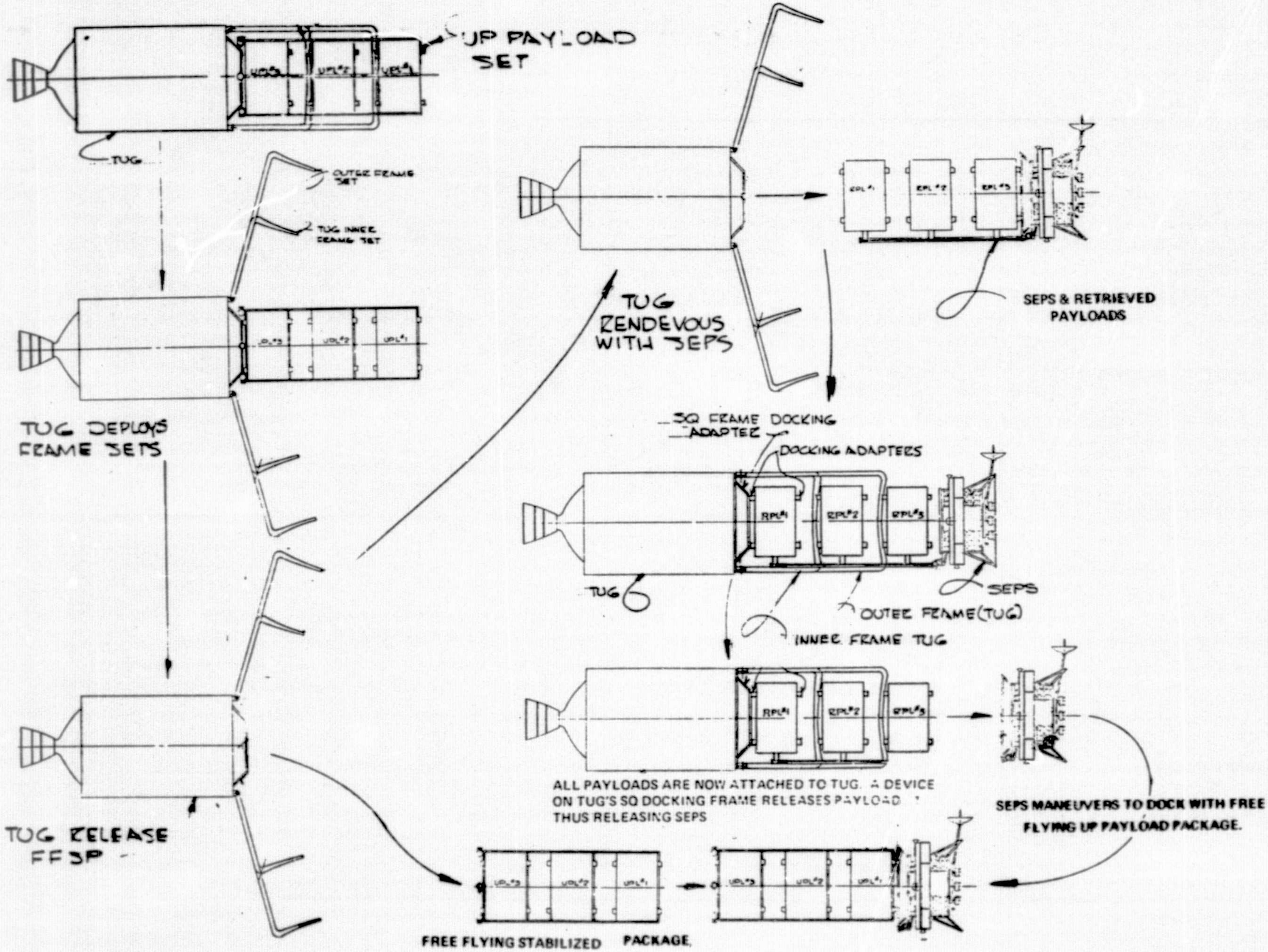
DOCK WITH NEXT PAYLOAD AFTER ROTATED 1ST PAYLOAD 180° TO CLEAR DOCKING FRAME



EXTEND MAST ATTACH #3 PAYLOAD TO MAST ROTATE #1 & #2 INTO FLIGHT POSITION

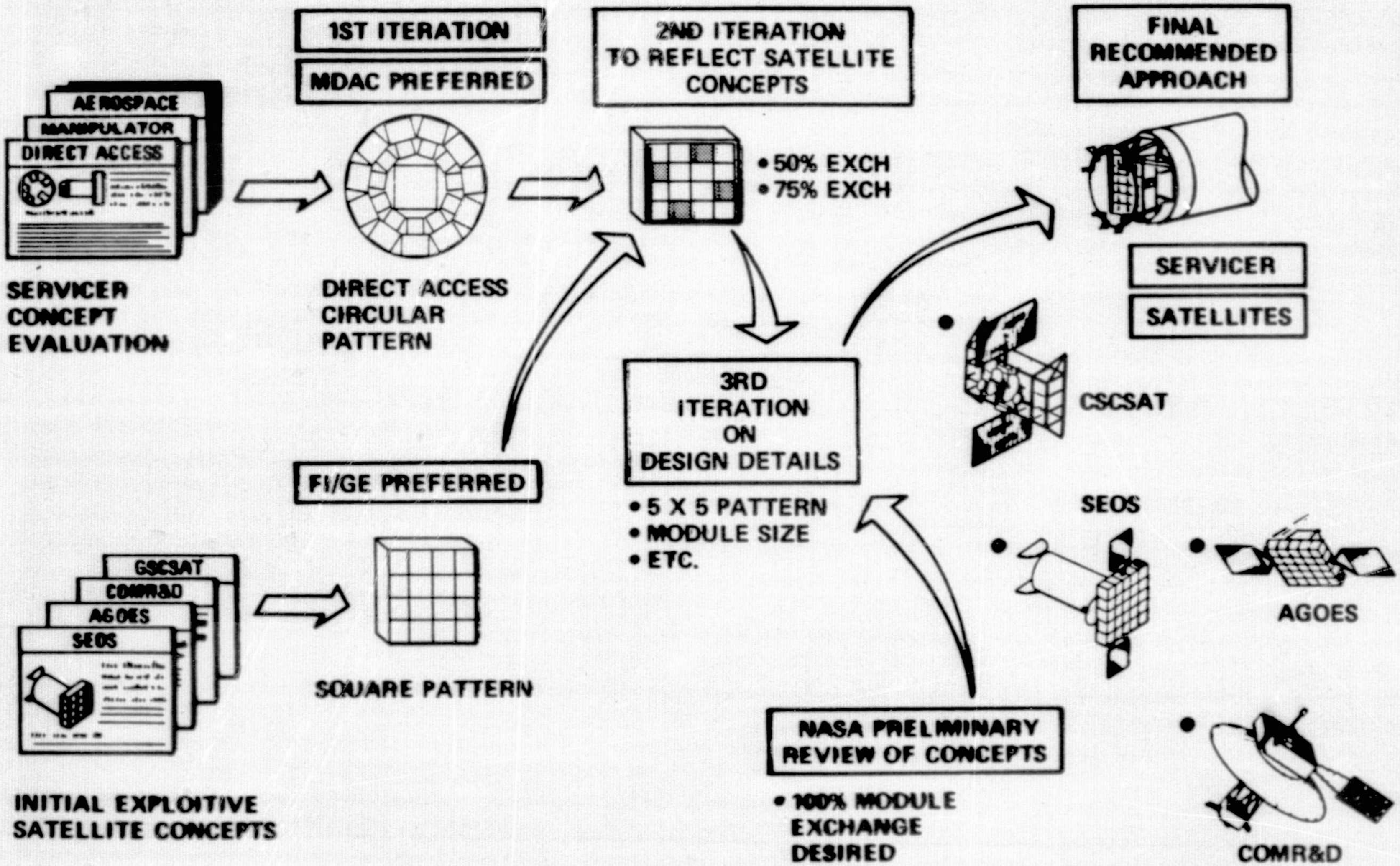
EXTEND MAST ROTATE #2 PAYLOAD 180° TO CLEAR DOCKING FRAME DOCK WITH #3 PAYLOAD

PAYLOAD RETRIEVAL SEQUENCE

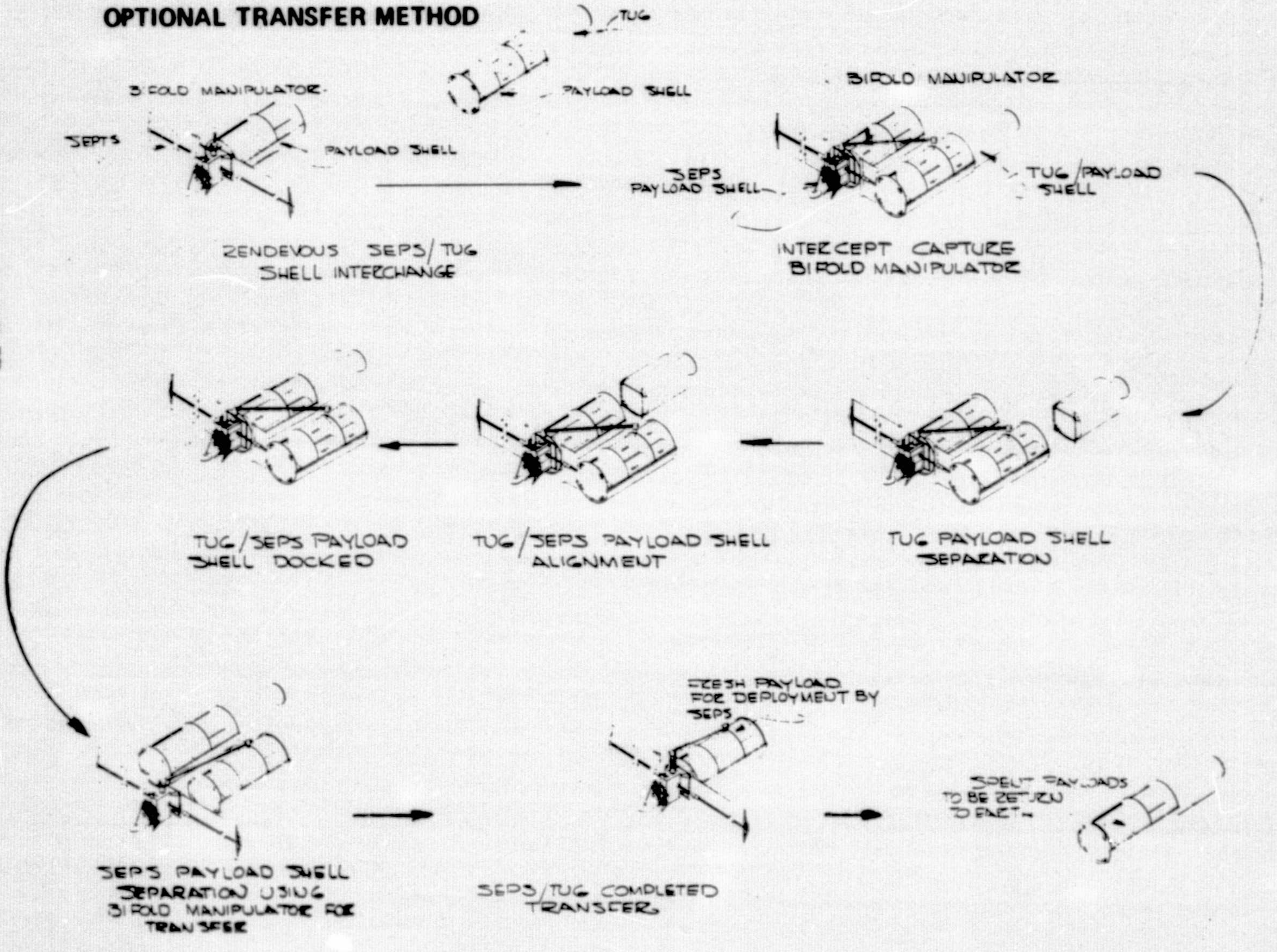


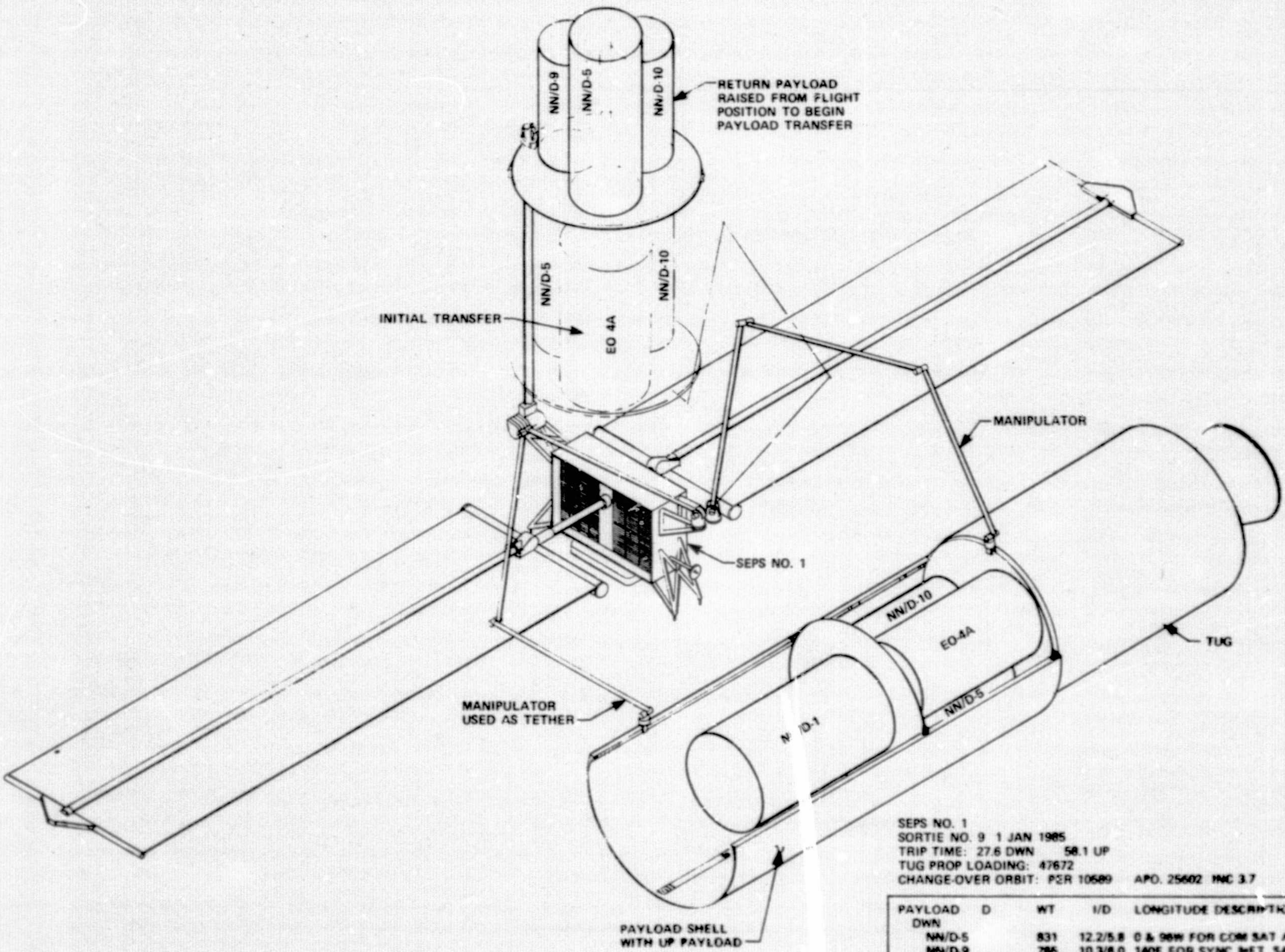
UP PAYLOAD SET
UPL#3
UPL#2
UPL#1
TUG
OUTER FRAME SET
TUG INNER FRAME SET
TUG DEPLOYS FRAME SETS
TUG RENDEVOUS WITH SEPS
RPL#1
RPL#2
RPL#3
SEPS & RETRIEVED PAYLOADS
SQ FRAME DOCKING ADAPTER
DOCKING ADAPTERS
TUG
SEPS
OUTER FRAME (TUG)
INNER FRAME TUG
ALL PAYLOADS ARE NOW ATTACHED TO TUG. A DEVICE ON TUG'S SQ DOCKING FRAME RELEASES PAYLOAD, THUS RELEASING SEPS
SEPS MANEUVERS TO DOCK WITH FREE FLYING UP PAYLOAD PACKAGE.
TUG RELEASE FFSP
FREE FLYING STABILIZED PACKAGE.

SERVICER CONCEPT EVOLUTION



OPTIONAL TRANSFER METHOD





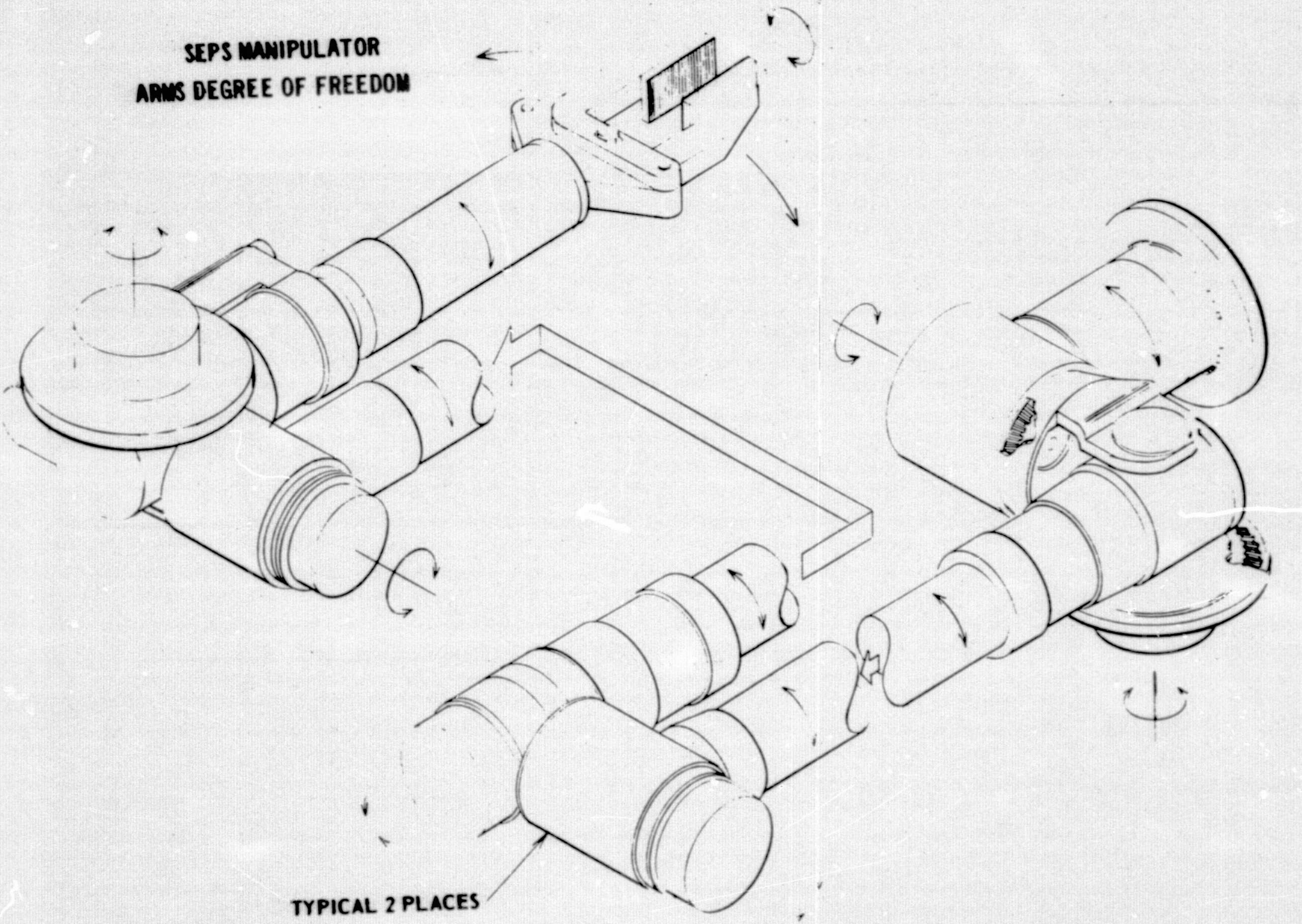
SEPS NO. 1
SORTIE NO. 9 1 JAN 1985
TRIP TIME: 27.6 DWN 58.1 UP
TUG PROP LOADING: 47672
CHANGE-OVER ORBIT: PER 10689 APO. 25602 INC 3.7

PAYLOAD	D	WT	I/D	LONGITUDE DESCRIPTION
DWN				
NN/D-5		831	12.2/5.8	0 & 96W FOR COM SAT A
NN/D-9		786	10.3/8.0	140E FOR SYNC MET. SAT.
NN/D-10		786	10.3/8.0	140E GEOSYNC OPER MET. SAT.
UP				
EO-4A		3085	11.0/7.4	100W SYNC. EARTH OBS.
NN/D-1		4498	12.2/8.3	40W & 180W INT. COM SAT
NN/D-5		982	12.2/5.8	0 & 96W FOR COM SAT B
NN/D-10		807	10.3/6.0	140E GEOSYNC OPEP MET SAT

PAYLOAD SUPPORT, HANDLING & SERVICING CONCEPT COMPARISON

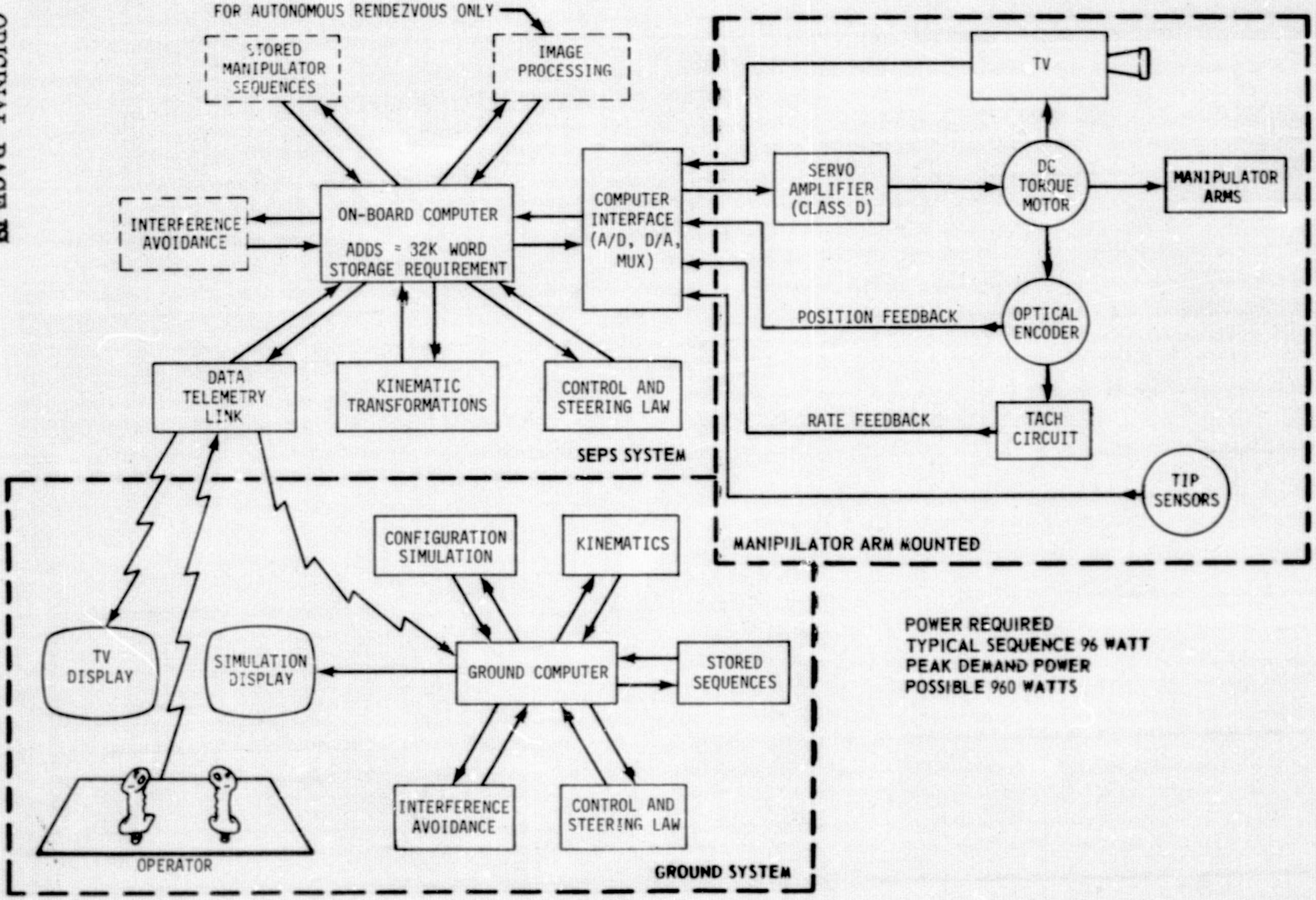
ARTICULATED DOCKING FRAME & PAYLOAD SUPPORT STRUCTURE	EXTENDABLE BOOM AND SIMPLIFIED MANIPULATOR	PAYLOAD MAST AND MANIPULATOR SYSTEM
ADVANTAGES • SIMPLEST ONBOARD SOFTWARE	ADVANTAGES • MODERATE ONBOARD SOFTWARE REQUIREMENT • SIMPLEST PAYLOAD TRANSFER FUNCTION	ADVANTAGES • GREATEST INHERENT CAPABILITY FOR PAYLOAD SERVICES AND MAINTENANCE • MINIMIZES DESIGN CONSTRAINTS ON PAYLOADS • SIMPLEST AND MOST FLEXIBLE INFLIGHT OPERATION • SIMPLEST GPME & TUG PAYLOAD INTEGRATION FUNCTION • HIGHEST MISSION SUCCESS PROBABILITY
DISADVANTAGES • MOST COMPLEX FLIGHT OPERATION • MOST COMPLEX FLIGHT HARDWARE • LIMITED GPME - REQUIRES TAILORING OF TUG MISSION EQUIPMENT & ORBITER TO PL ADAPTERS FOR EACH SORTIE • EITHER SERIOUS PL DESIGN CONSTRAINT OR VERY LIMITED SERVICING ABILITY • NOT ADAPTABLE TO UNFORESEEN OR UNPLANNED MISSION EVENTS • COMPONENTS REQUIRING POSITIONING & FEEDBACK INFO EXCEED OTHER SYSTEMS	DISADVANTAGES • LIMITED SERVICING AND ONORBIT MAINTENANCE ABILITY • INTERMEDIATE ADAPTABILITY TO UNPLANNED MISSION EVENTS	DISADVANTAGES • ONBOARD SOFTWARE REQUIRES ~ 32K WORD MEMORY STORAGE

SEPS MANIPULATOR
ARMS DEGREE OF FREEDOM

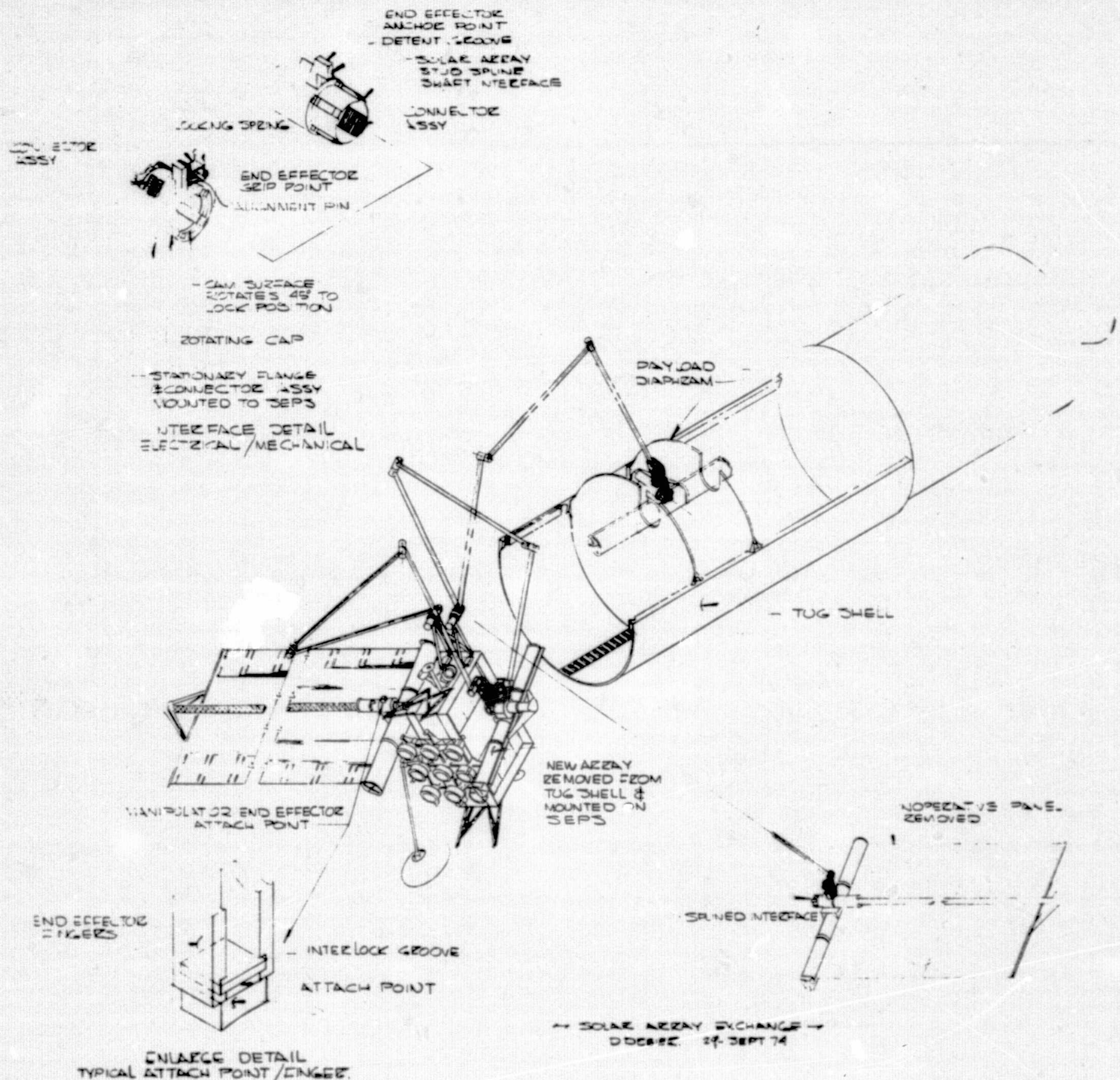


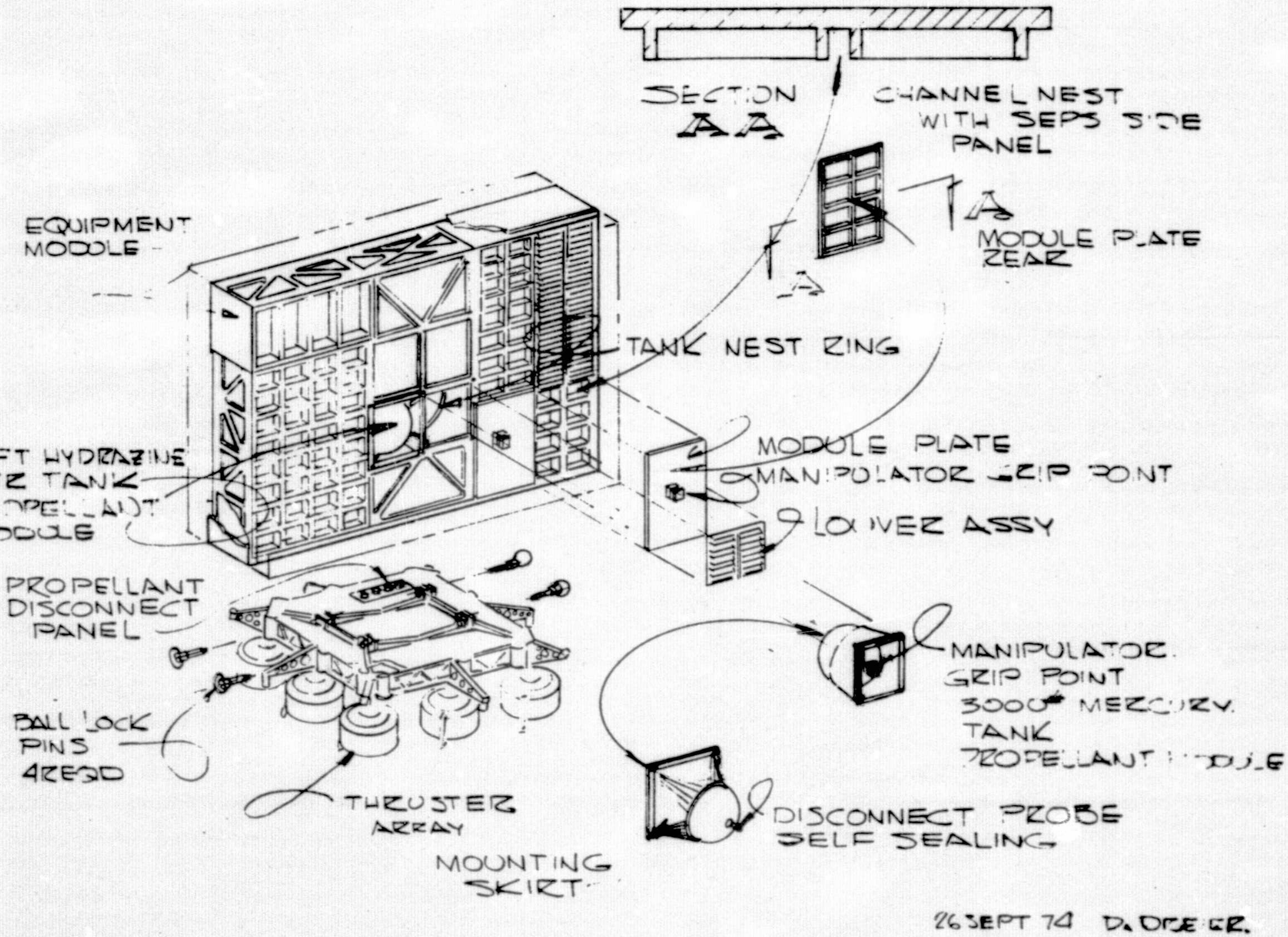
ORIGINAL PAGE IS OF POOR QUALITY

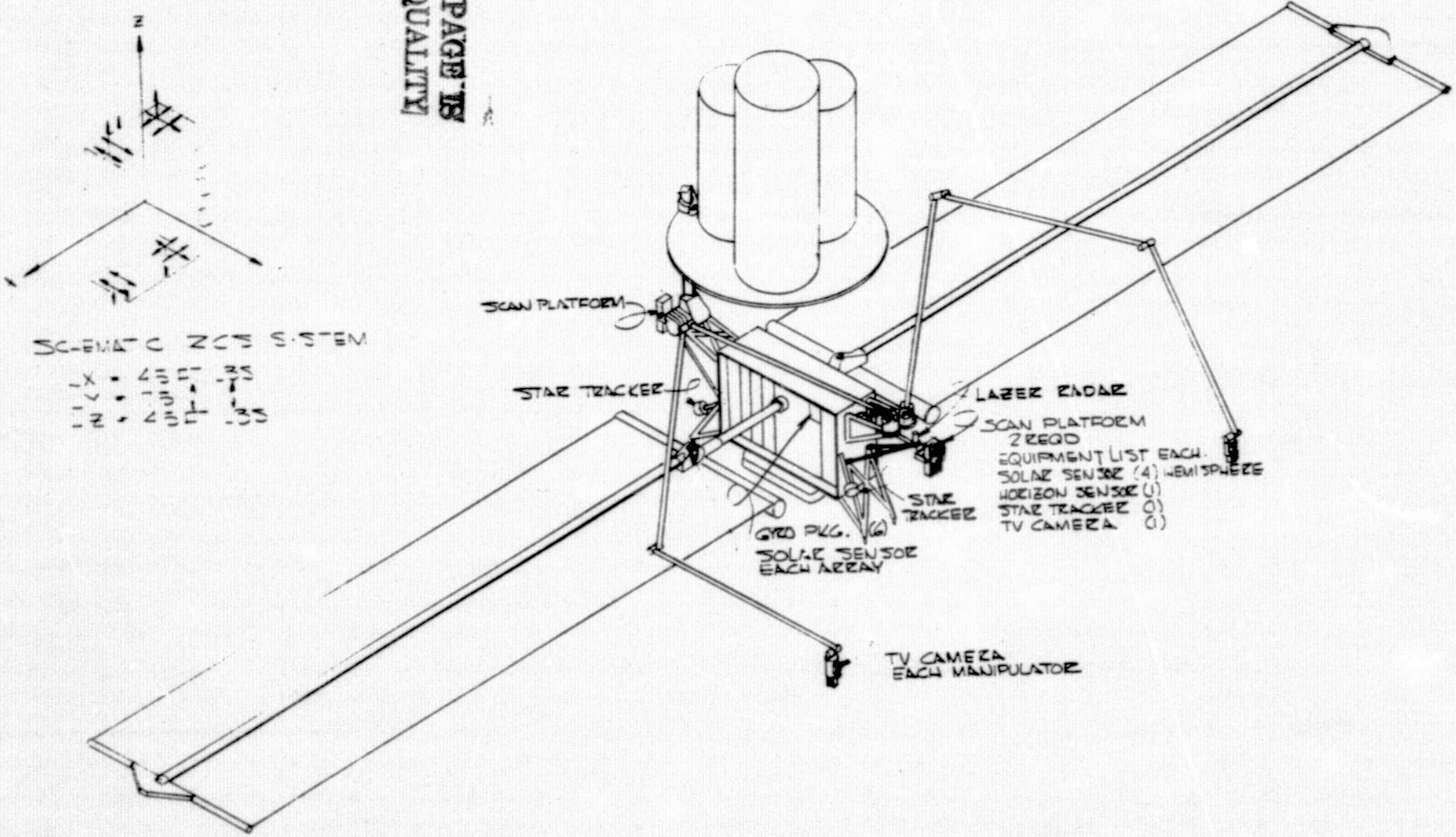
MANIPULATOR SYSTEM SCHEMATIC

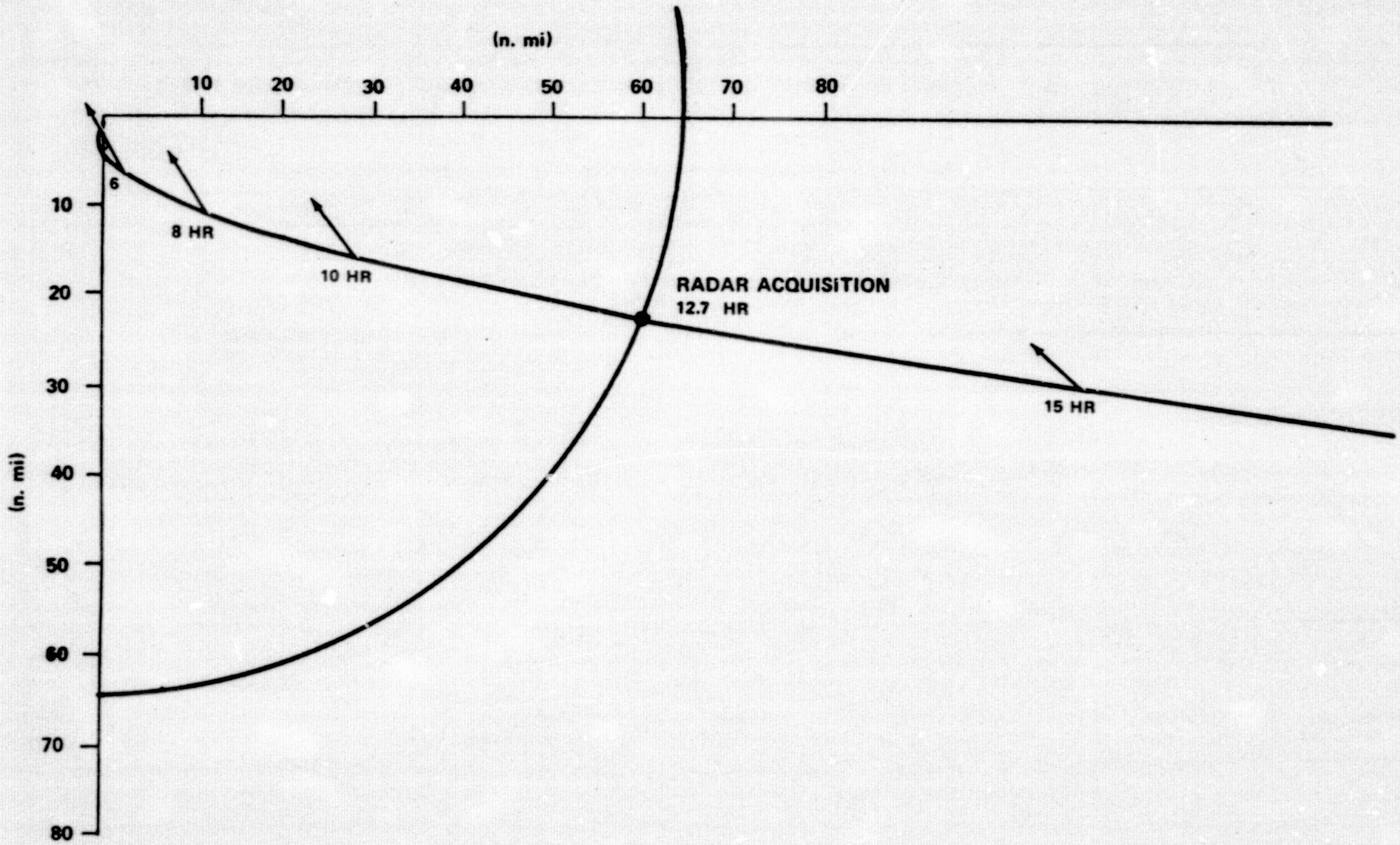


POWER REQUIRED
TYPICAL SEQUENCE 96 WATT
PEAK DEMAND POWER
POSSIBLE 960 WATTS

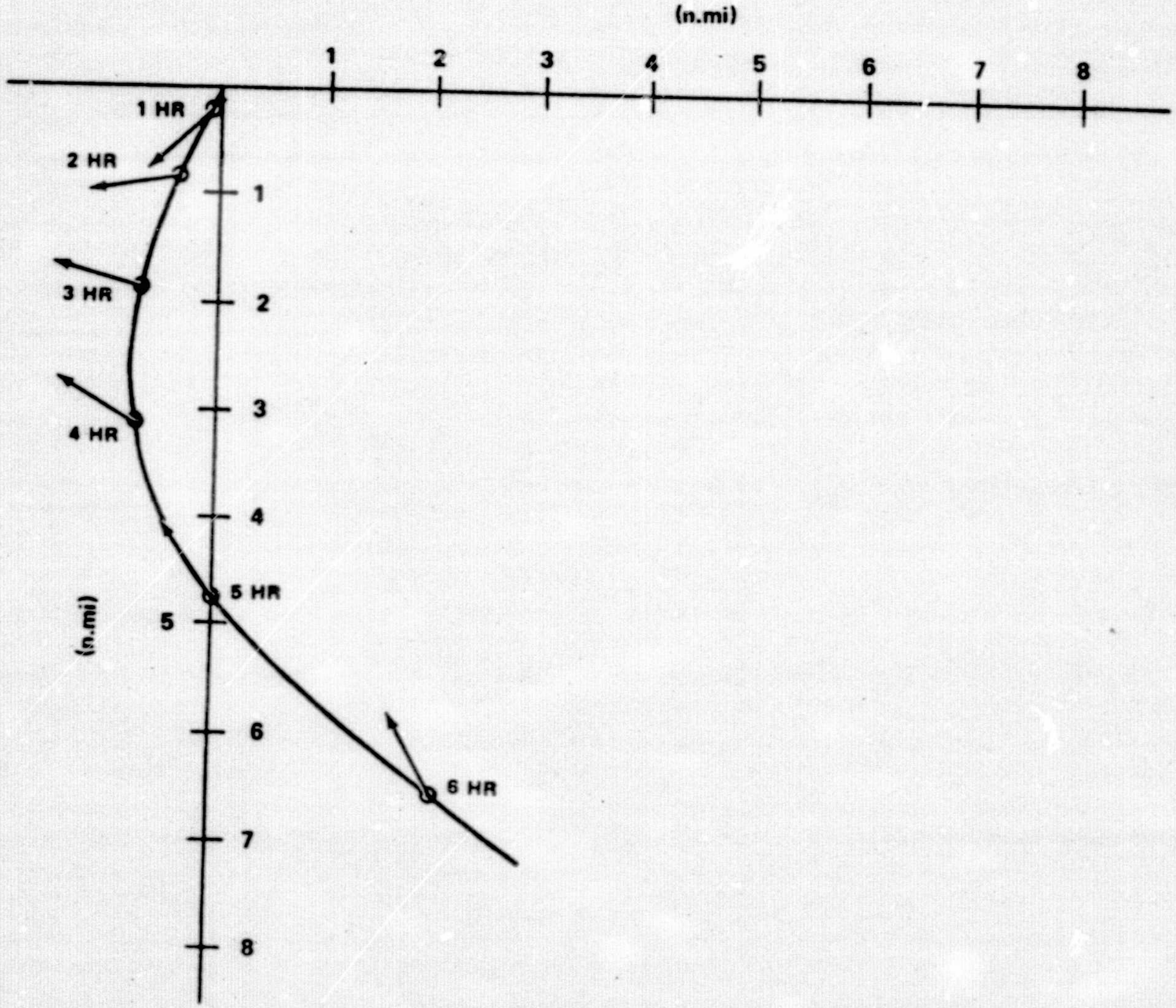

END EFFECTOR
ANCHOR POINT
DETENT GROOVE
SOLAR ARRAY
STUD SPLINE
SHAFT INTERFACE
LOCKING SPRING
CONNECTOR
ASSY
CONNECTOR
ASSY
END EFFECTOR
GRIP POINT
ALIGNMENT PIN
CAM SURFACE
ROTATES 45° TO
LOCK POSITION
ROTATING CAP
STATIONARY FLANGE
& CONNECTOR ASSY
MOUNTED TO SEPS
INTERFACE DETAIL
ELECTRICAL/MECHANICAL
PAYLOAD
DIAPHRAM
TUG SHELL
NEW ARRAY
REMOVED FROM
TUG SHELL &
MOUNTED ON
SEPS
MANIPULATOR END EFFECTOR
ATTACH POINT
INOPERATIVE PANEL
REMOVED
SPLINED INTERFACE
END EFFECTOR
FINGERS
INTERLOCK GROOVE
ATTACH POINT
ENLARGE DETAIL
TYPICAL ATTACH POINT/FINGER
SOLAR ARRAY EXCHANGE
D DEBEE 27 SEPT 74


SECTION
AA
CHANNEL NEST
WITH SEPS SIDE
PANEL
MODULE PLATE
REAR
EQUIPMENT
MODULE
TANK NEST RING
2 CUFT HYDRAZINE
SPHER TANK
RCS PROPELLANT
MODULE
MODULE PLATE
MANIPULATOR GRIP POINT
LOUVER ASSY
PROPELLANT
DISCONNECT
PANEL
MANIPULATOR
GRIP POINT
3000# MERCURY
TANK
PROPELLANT MODULE
BALL LOCK
PINS
4 REQD
THRUSTER
ARRAY
DISCONNECT PROBE
SELF SEALING
MOUNTING
SKIRT
26 SEPT 74 D. DREIER.


SCAN PLATFORM
STAR TRACKER
LAZER RADAR
SCAN PLATFORM
2 REQD
EQUIPMENT LIST EACH.
SOLAR SENSOR (4) HEMISPHERE
HORIZON SENSOR (1)
STAR TRACKER (1)
TV CAMERA (1)
STAR TRACKER
GYRO PKG. (6)
SOLAR SENSOR EACH ARRAY
TV CAMERA EACH MANIPULATOR



(n. mi)
10
20
30
40
50
60
70
80
6
8 HR
10 HR
RADAR ACQUISITION
12.7 HR
15 HR
(n. mi)
10
20
30
40
50
60
70
80


(n.mi)
1
2
3
4
5
6
7
8
1 HR
2 HR
3 HR
4 HR
5 HR
6 HR
(n.mi)

ATTITUDE CONTROL REQUIREMENTS

- BASIC - MAN-IN-THE-LOOP MANEUVERING

- ACCURACY

  ATTITUDE $\pm$ 0.1 DEG

  RATE $\pm$ .002 DEG/SEC

- ACCELERATION CAPABILITY (LOADED)

  TRANSLATION 10^{-3} FT/SEC^2

  ROTATION 1.5×10^{-5} RAD/SEC^2

- IMPLIED FORCES

  THRUST 0.5 LB

  PITCH TORQUE .16 FT LB

  ROLL & YAW TORQUE 0.82 FT LB

ATTITUDE SENSORS

- RATE GYROS (6 IN DODECAHEDRON)
- SOLAR SENSORS (10)
- HORIZON SENSORS (2)
- STAR TRACKERS (4)
- TV CAMERAS (4)
- LASER RADAR (1)

ASSESSMENT OF SUPPORTING TECHNOLOGY BASE

- THRUSTERS HAVE THE INHERENT ABILITY TO OPERATE OVER VOLTAGE RANGES OF LESS THAN 800V TO MORE THAN 2800V AND BEAM CURRENTS CORRESPONDING TO .5 TO MORE THAN 4 AMP IN A 30 CM THRUSTER

- SOLAR ARRAYS ARE BOTH FEASIBLE AND DESIRABLE DIRECT SOURCES OF THRUSTER BEAM POWER

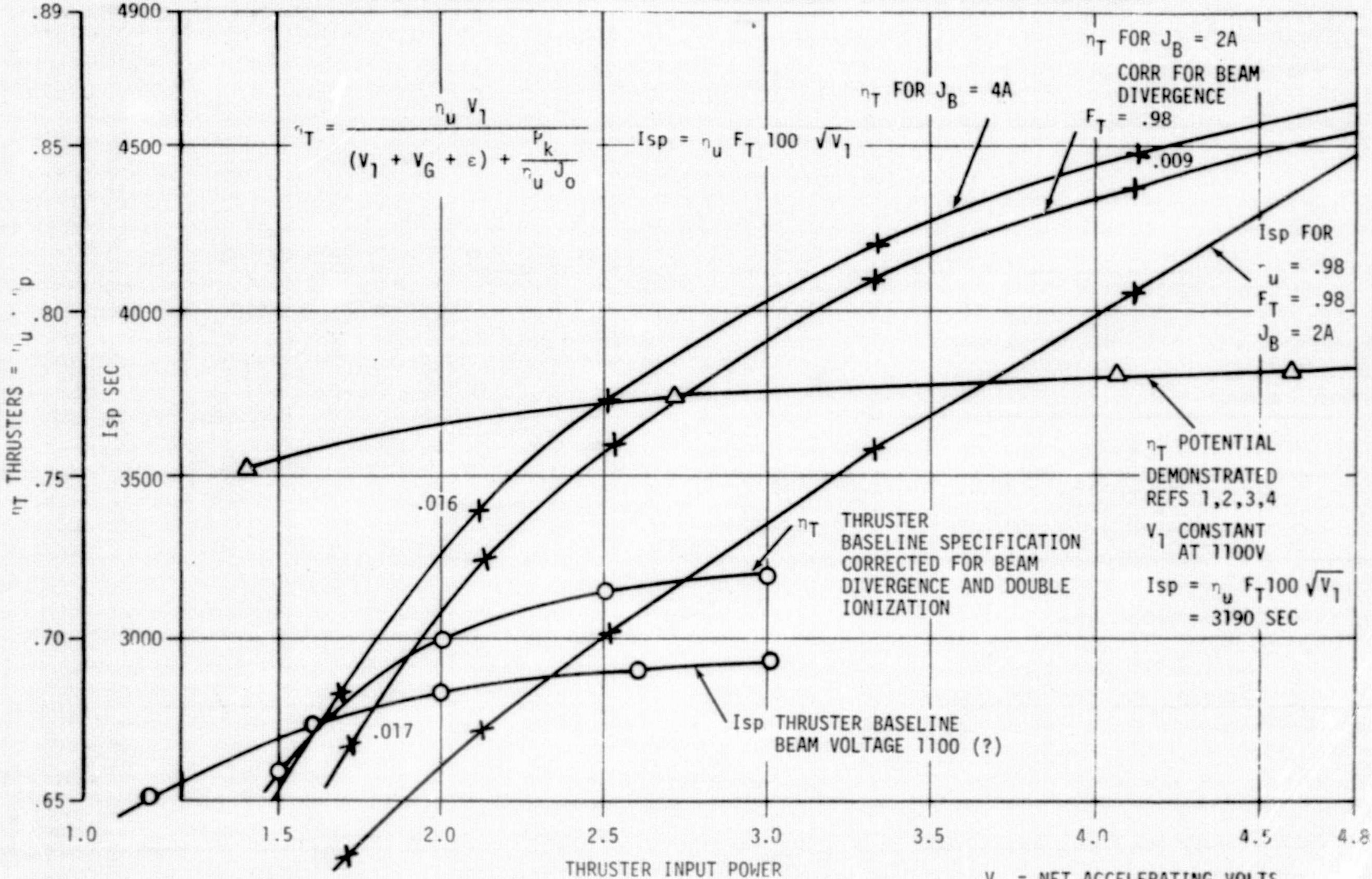
- HIGHER VOLTAGE SOLAR ARRAYS ARE FEASIBLE AND DESIRABLE

- POTENTIAL EXISTS FOR LOWER COST AND HIGHER RELIABILITY SOLAR ARRAYS

- HIGHER VOLTAGE POWER PROCESSORS ARE FEASIBLE

- EXPLOITATION OF THE TECHNOLOGY BASE PROVIDES SIGNIFICANTLY MORE MISSION FLEXIBILITY THAN BASELINE.

ION PROPULSION DEMONSTRATED POTENTIAL COMPARED TO SEPS BASELINE FOR STUDY



V_1 = NET ACCELERATING VOLTS

$\eta_u J_o$ = J_B = BEAM CURRENT

P_k = THRUSTER FIXED POWER LOSSES

η_u = PROPELLANT UTILIZATION EFF.

ε = DISCHARGE LOSS ev/ION

V_G = NEUTRALIZER TO BEAM VOLTAGE

CONSIDERATIONS FOR DIRECT USE OF SOLAR ARRAY POWER

- ARRAY IS AN IDEAL RIPPLE FREE DC SOURCE, CURRENT LIMITED AND SELF PROTECTING
- THRUSTERS SCREEN POWER IS A RELATIVELY SLOW CHANGING LOAD SELF LIMITING IN CURRENT DEMAND (EXCEPT FOR ARCING)
- THRUSTER ARCING (CONTAMINATION CAUSED?) IS MORE HAZARDOUS TO PCs THAN TO ARRAYS. CONTROL TECHNIQUES EXIST FOR BOTH
- THRUSTER PRIMARY CONTROL IS MAIN VAPORIZER.

IMPLEMENTATION CONSIDERATIONS FOR EXPLOITING THE TECHNOLOGY BASE

I. SCREEN POWER MAY BE TAKEN DIRECTLY FROM SOLAR ARRAYS

SCREEN POWER IS ≈ 75% OF TSS TOTAL
≈ 70% OF WEIGHT OF PC
≈ 70% OF HEAT GENERATED

SCREEN PC ARE ONLY 92% EFFICIENT

ARRAY WT INCREASE IS 8.8 x .75 = 8.1%

ARRAY IS MOST EXPENSIVE SUBSYSTEM

ARRAYS WEIGH ≈ 33 LB/KW

PCs WEIGH ≈ 7.7 LB/KW

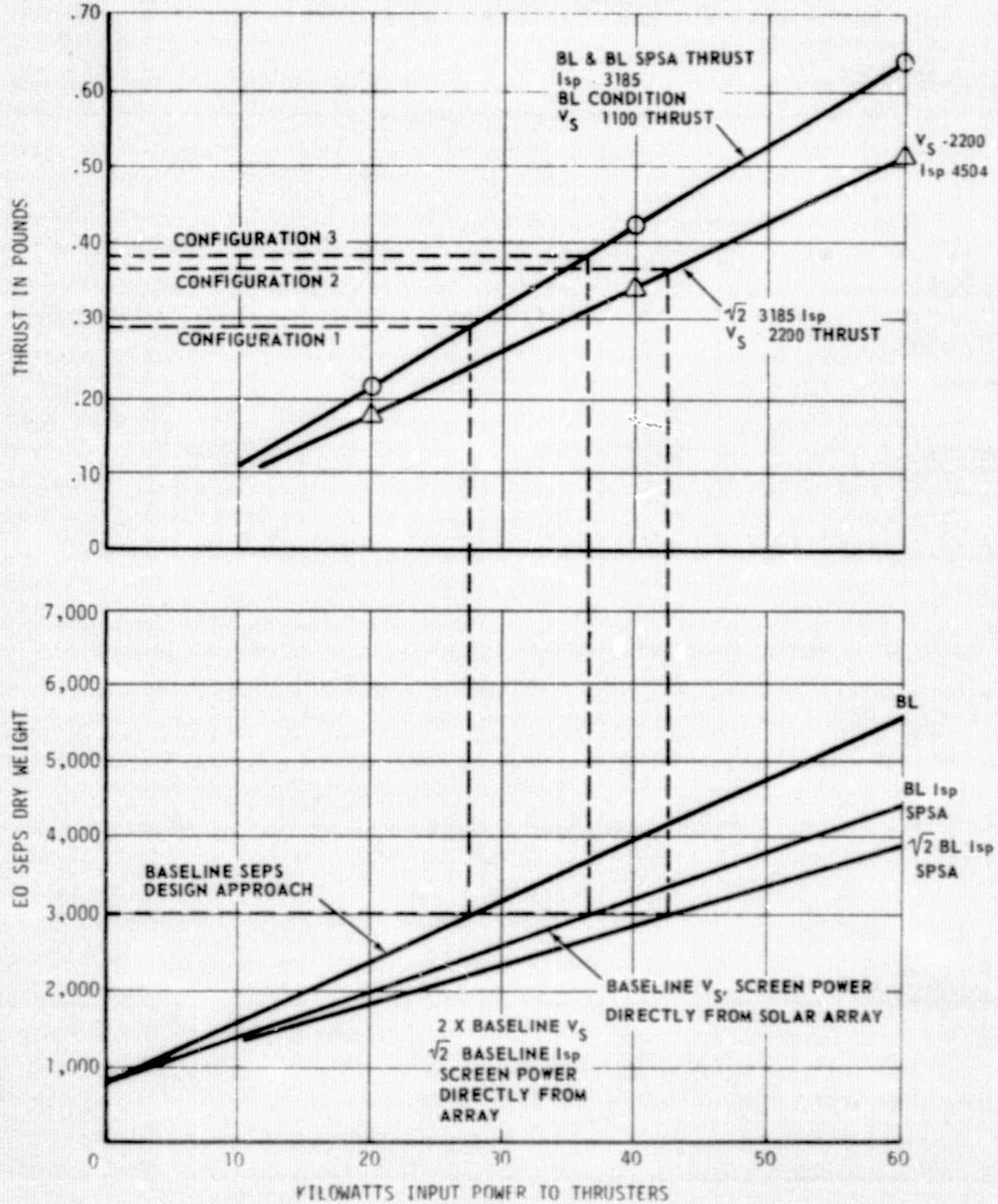
POWER SUPPLY TOTAL ≈ 40.7 LB/KW

Δ WT DUE TO USE OF SCREEN PCs = .08 x 33 + 7.7 x .75
= 8.5 LB/KW

Δ WT SAVING POTENTIAL ≈ 20%

Δ POWER GAIN FOR SAME WT 8.5/32.2 = 26%

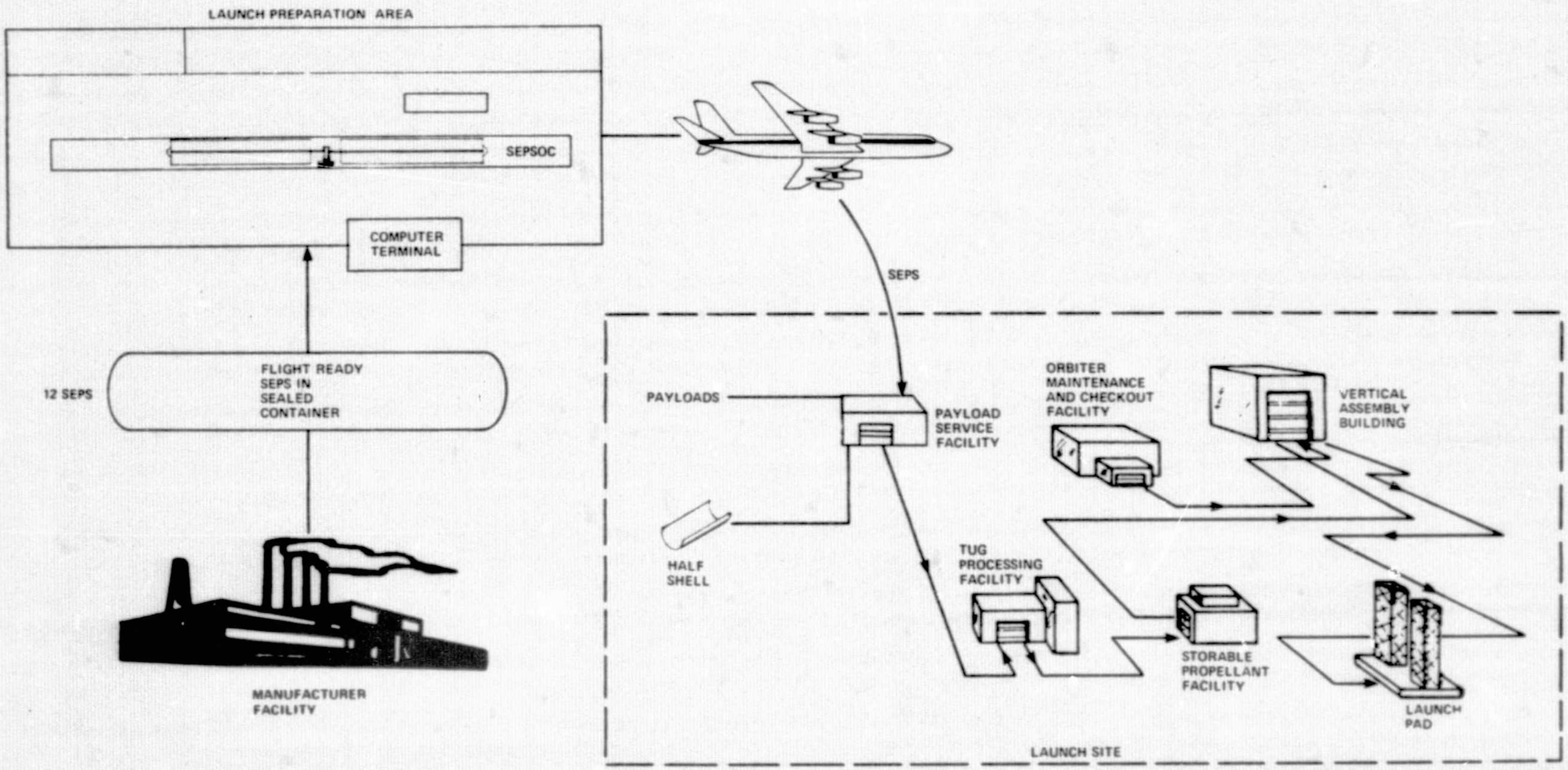
EARTH ORBITAL SEPS PARAMETRIC WEIGHT & THRUST DATA VS THRUSTER INPUT POWER
FOR BL & ALTERNATE APPROACHES



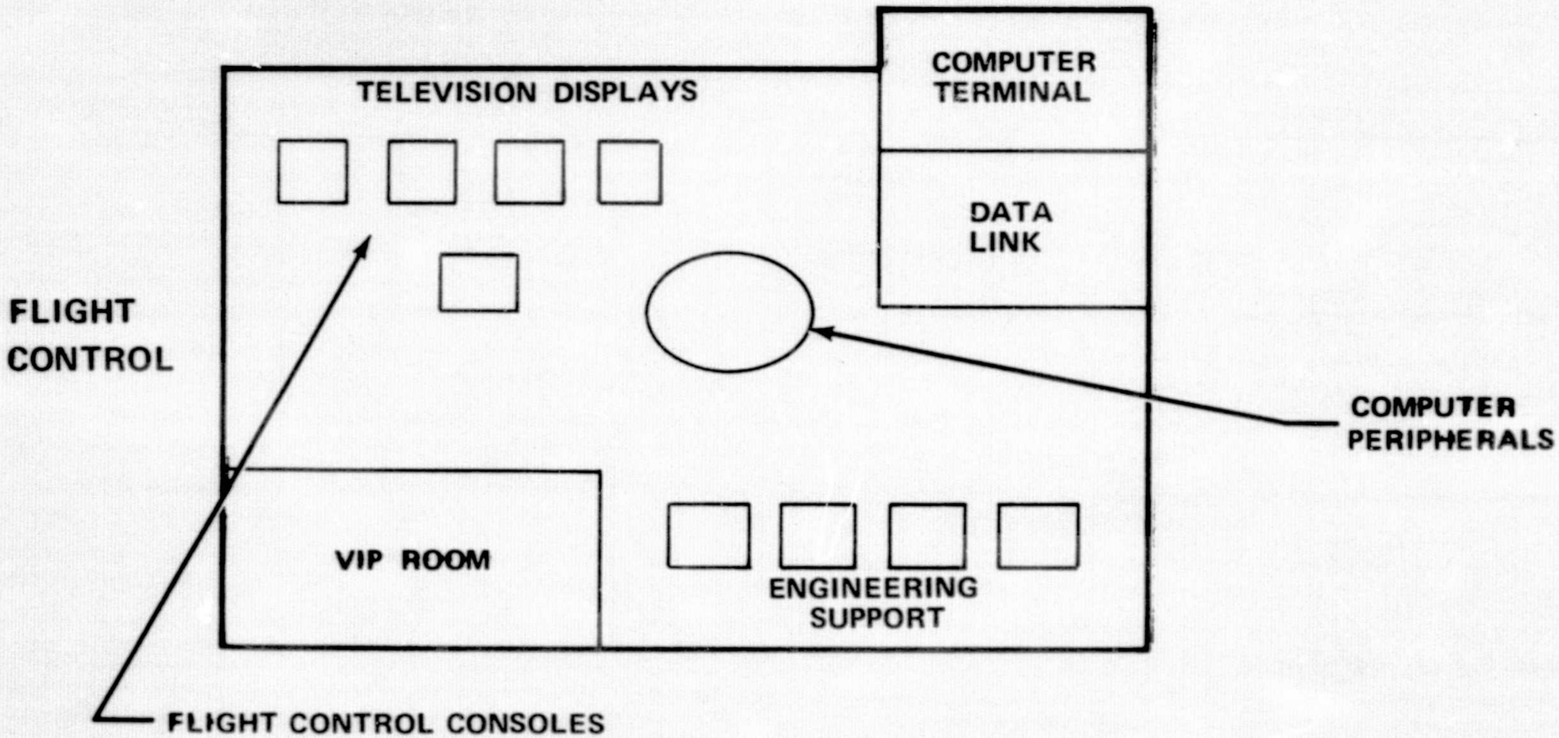
SEPS PROGRAM SUPPORT REQUIREMENTS

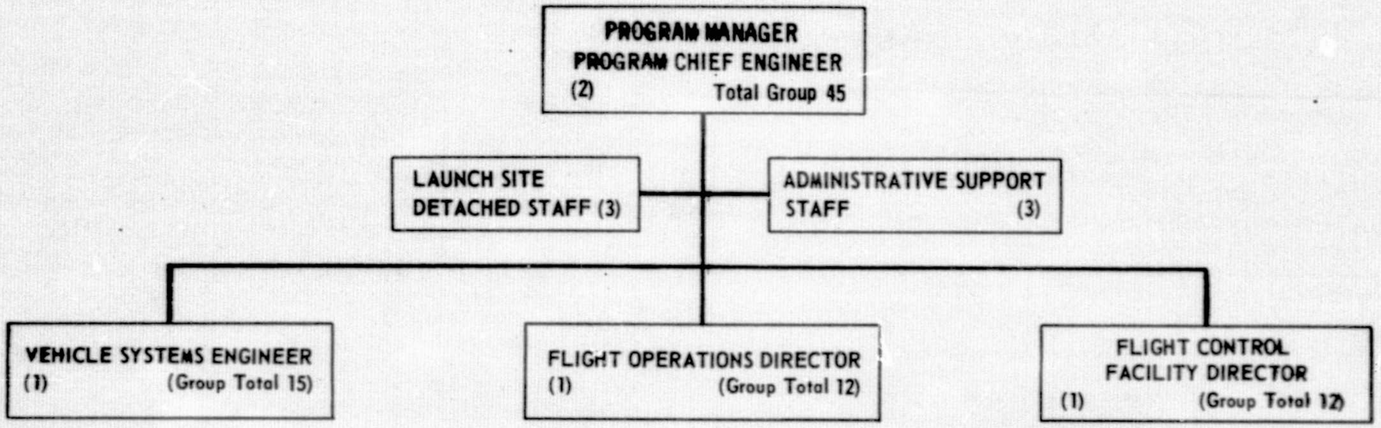
- LAUNCH PREPARATION
- FLIGHT CONTROL OPERATIONS
- MISSION PLANNING
- MAINTENANCE & REFURBISHMENT
- PROGRAM SUPPORT REQUIREMENTS
    - EQUIPMENT & FACILITIES
    - SOFTWARE
    - PERSONNEL
- COST

SEPS LAUNCH PREPARATION



(SEPSOC) SEPS OPERATIONS CENTER





FUNCTIONS

SUSTAINING ENGINEERING AND MAINTENANCE DIRECTION FOR SEPS AND ASSOCIATED GSE

FLIGHT OPERATIONS CONTROL OF SEPS SUBSYSTEMS

SUSTAINING ENGINEERING AND MAINTENANCE DIRECTION FOR CONTROL CENTER CONSOLES

SOFTWARE DEFINITION/GENERATION FOR CHECKOUT, MONITORING, AND OPERATION OF SEPS SUBSYSTEMS

LAUNCH PREPARATION & LAUNCH SUPPORT

STAFFING

PROPULSION AND MECHANICAL SYSTEMS ENGR (4)

AVIONICS SYSTEMS ENGINEER (4)

PAYLOAD TRANSPORT/SERVICING SYSTEMS ENGR (5)
(THESE MEN ARE ALSO THE SEPS PILOTS FOR RENDEZVOUS AND MANIPULATION OPERATIONS)

FUNCTIONS

MISSION PLANNING AND SIMULATION

REAL TIME MISSION SUPPORT

NEW SOFTWARE DEVELOPMENT AND MAINTENANCE

STAFFING

FLIGHT DYNAMICS ENGINEER (6)

SOFTWARE MANAGER (5)

FUNCTIONS

DATA SYSTEM MANAGEMENT

COMPUTER OPERATIONS MANAGEMENT (PRINCIPALLY COORDINATION OF PRIORITIES AND SCHEDULE WITH A NONDEDICATED COMPUTER COMPLEX)

DATA TRANSMISSION LINE MANAGEMENT

CONTROL CENTER MAINTENANCE

STAFFING

FLIGHT SUPPORT DIRECTOR (2)

DATA SYSTEM MANAGER (6)

CONTROL CENTER MAINTENANCE (3)

ENTIRE GROUP SUPPORTS A RENDEZVOUS AND PAYLOAD TRANSFER OPERATION. FCC STAFFING DURING THIS PERIOD IS 16.

OPERATIONS COST TOTAL MISSION CYCLE

START UP COST	
*EQUIPMENT	$ 6,400,000
MAINTENANCE & REFURBISHMENT	8,000,000
SOFTWARE	8,700,000
FACILITIES	700,000
	23,800,000
PERSONNEL	23,700,000
COMPUTER OPERATION	2,100,000
	25,800,000

PERSONNEL/COMPUTER OPERATION $25,800,000 11 YEAR MISSION MODEL

÷ 29 SORTIES = $889,655 PER SORTIE

**Includes 5.3 mil. for computer*

SEPS PROGRAM BASIC ASSUMPTIONS

1. COST ANALYSIS DATA IS BASED ON A SINGLE SEPS DDT&E AND PRODUCTION PROGRAM

    - o BASIC SEPS "CORE"
    - o PLANETARY KIT
    - o EARTH ORBITAL KIT

2. KIT CONTENT REQUIRES FURTHER DEFINITION

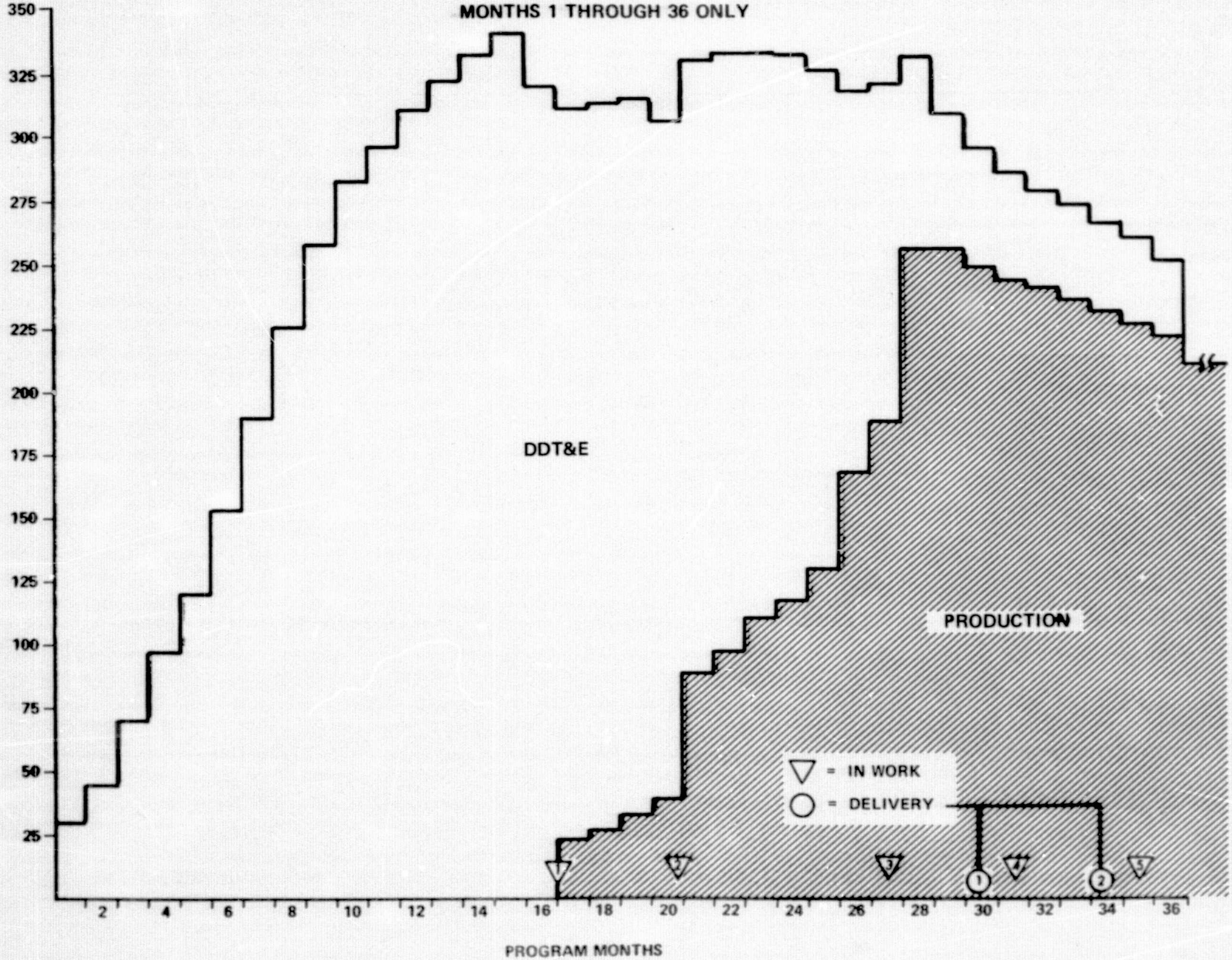
    - o KIT COST REPRESENTS $\simeq$ 10-15% OVER BASIC SEPS "CORE"
    - o KIT COST $\simeq$ SAME

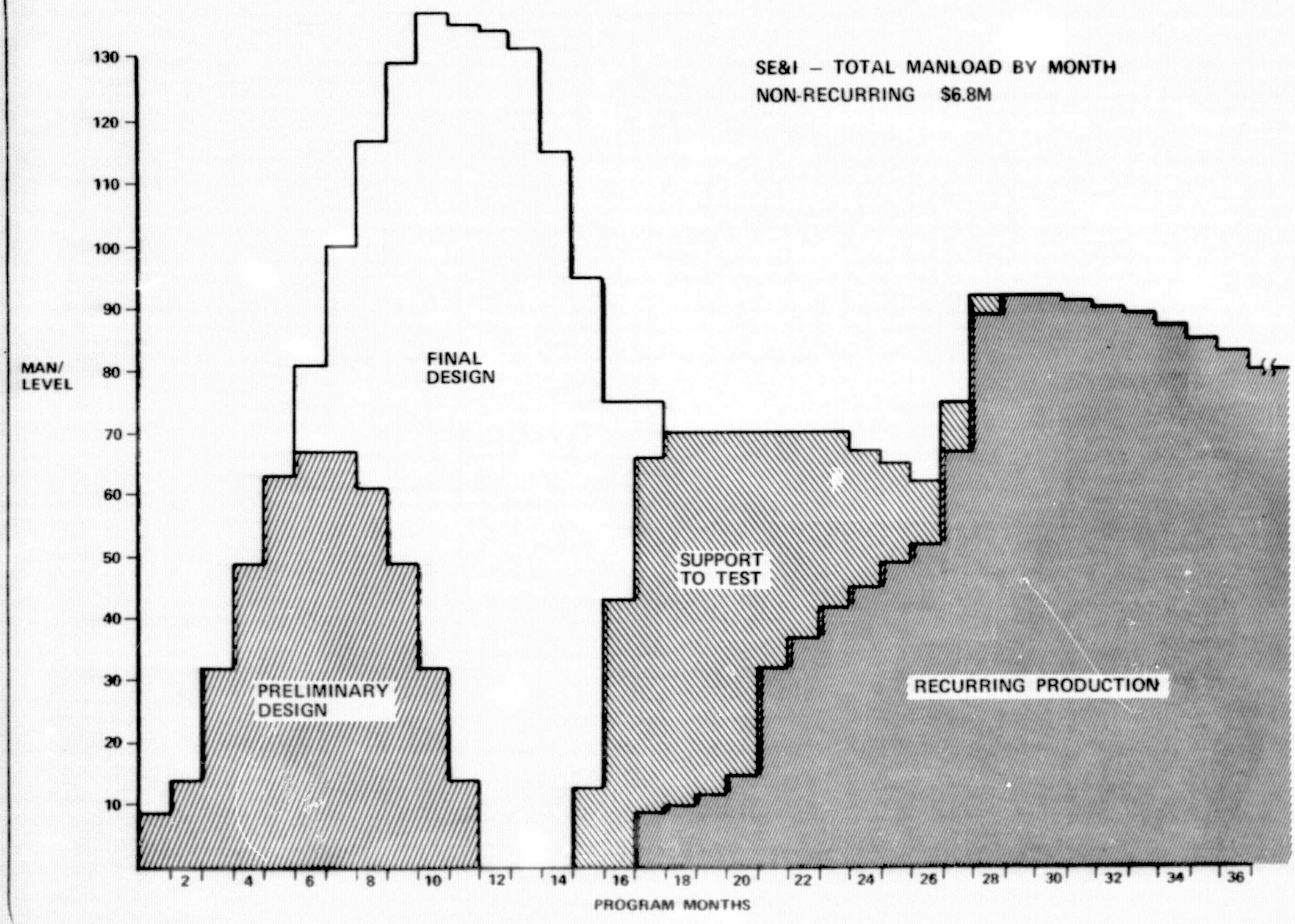
3. EARTH ORBITAL DELTA COSTS PRESENTED REPRESENT PAYLOAD TRANSPORT AND SERVICING SYSTEM
   (MANIPULATOR ARM SYSTEM AND PAYLOAD MAST)

SEPS DEVELOPMENT COSTS

STRUCTURES & THERMAL CONTROL	$ 4.8 M
PROPULSION	9.1
POWER DISTRIBUTION	1.0
SOLAR ARRAY	7.8
DATA MANAGEMENT	3.4
COMMUNICATION	2.2
ATTITUDE CONTROL	9.2
INTEG. & TEST CHECKOUT	6.7
TEST HARDWARE	21.3
G.S.E.	10.0
SOFTWARE	4.5
LOGISTICS	2.2
S.E.&I.	6.8
PROGRAM MANAGEMENT	6.9
BASIC SEPS	$ 95.9 M
Δ FOR EARTH ORBITAL FUNCTIONS	8.3
	$104.2 M
Δ FOR TUG PAYLOAD SHELL & DIAPHRAGMS	2.5
	$106.7 M

TOTAL SEPS PROGRAM MANLOAD
MONTHS 1 THROUGH 36 ONLY

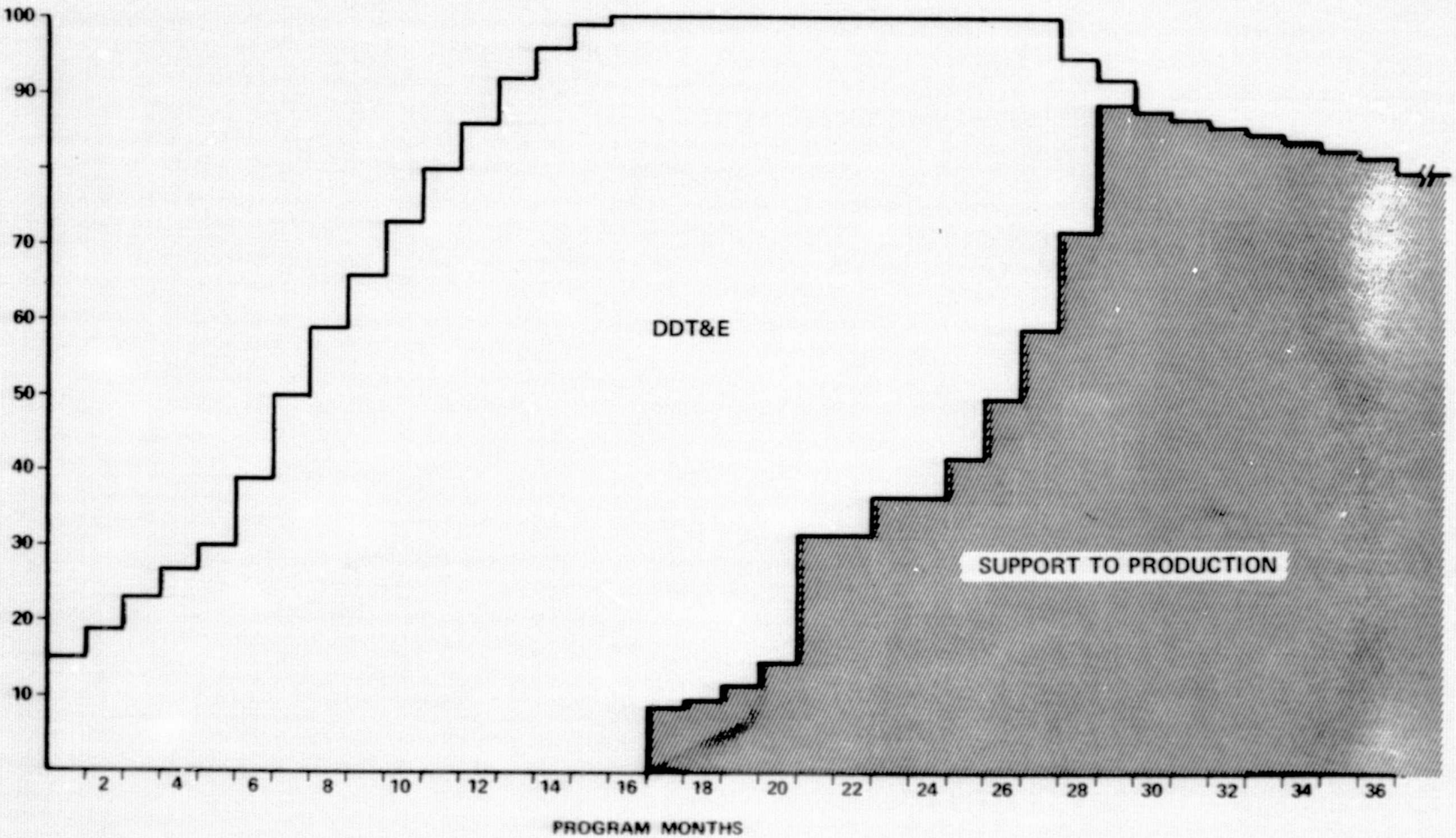




SE&I – TOTAL MANLOAD BY MONTH
NON-RECURRING $6.8M
MAN/ LEVEL
130
120
110
100
90
80
70
60
50
40
30
20
10
FINAL DESIGN
PRELIMINARY DESIGN
SUPPORT TO TEST
RECURRING PRODUCTION
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
PROGRAM MONTHS

PROGRAM MANAGEMENT

DDT&E $6.9M



RECURRING COSTS - ASSUMPTIONS AND CONDITIONS

1. COSTS ARE IN 1974 DOLLARS

2. PRODUCTION IS CONTINUOUS AND INCLUDES 11 UNITS (8 WITH PLANETARY KITS - 3 WITH EARTH ORBITAL KITS)

3. FIRST UNIT COST UTILIZED IS $17.5M

4. AVERAGE CURVE FACTOR FOR 11 UNITS IS 69.4% OF FIRST UNIT COST. (REFERENCE N.S.I. RECOMMENDED IMPROVEMENT CURVE)

SEPS SUMMARY COSTS

	BASIC SEPS	Δ FOR E.O. FUNCTIONS	TUG P/L SHELL AND DIAPHRAGMS	TOTAL
NON-RECURRING COSTS:				
STAGE DDT&E	$ 95.9 M	$ 8.3 M	$2.5 M	$106.7 M
SEPSOC EQUIPMENT	6.4*			6.4**
SEPSOC FACILITIES	.7			.7
SEPSOC SOFTWARE	8.7**			8.7**
TOTAL NON-RECURRING	111.7	8.3	2.5	122.5
PRODUCTION COSTS	133.7 (11 UNITS)	2.7 (3 UNITS)	1.5 (2 UNITS)	137.9
OPERATION COSTS	33.8			33.8
GRAND TOTALS	$ 279.2 M	$ 11.0 M	$4.0 M	$294.2 M

*Includes $5.3M for computer

**Additional $4.5M included in stage DDT&E (Total $13.2M)

SYSTEM OPERATIONAL PROFILE AND TRANSPORT COST EFFECTIVENESS ANALYSIS ACCOMPLISHMENTS

- DEFINITION OF OPERATIONAL MODES FOR NEAR MINIMUM STS FLIGHTS WITH MINIMUM SEPS TRIP TIMES DEFINED
- IMPLEMENTATION OF MODES IN A COMPUTER PROGRAM FOR MASTER SCHEDULING AND PAYLOAD ASSIGNMENT TO SPECIFIC FLIGHTS
- IDENTIFICATION OF MODIFIED BASELINE SEPS TRANSPORTATION SYSTEM SAVINGS
- IDENTIFICATION OF INCREASED POWER & I_{sp} ADVANTAGES
- IDENTIFICATION OF RADIATION DAMAGE EFFECTS FROM "OPTIMUM" TRIP TIME SORTIES
- IDENTIFICATION OF MOST PROMISING SEPS CHARACTERISTICS
- SENSITIVITY OF STS FLIGHTS REQUIRED TO OPERATIONAL CONSTRAINTS

CONCLUSIONS REGARDING OPERATIONAL MODES, CONFIGURATION DEFINITION AND SUBSYSTEM CHARACTERISTICS

- TRANSPORTATION ECONOMY REQUIRES ABILITY TO HANDLE 5 OR MORE PAYLOADS PER FLIGHT WITHOUT MISSION SPECIALIZED EQUIPMENT
- SEPS OPERATIONAL PHASE CAN BE SUPPORTED BY A 45 MAN TEAM
- ELLIPTICAL SEPS-TUG TRANSFER ORBITS OFFER APPRECIABLE TRIPTIME SAVINGS
- SEPS TRANSPORT CAPABILITIES ARE ALMOST DIRECTLY PROPORTIONAL TO POWER. PLANETARY MISSION CAPABILITY IS ENHANCED BY INCREASED POWER
- MANIPULATOR-MAST-TRANSPORT SHELL GPME OFFERS THE MOST ALL AROUND ADVANTAGES
- SCREEN POWER DIRECTLY FROM SOLAR ARRAYS OFFERS LOWER COST, INHERENT I_{sp} SELECTIVITY TO MATCH MISSION REQUIREMENTS, LOWER WEIGHT AND INCREASED RELIABILITY
- THE THRUSTER TECHNOLOGY BASE SUPPORTS DEVELOPMENT GOALS CORRESPONDING TO OPERATION OF 30 CM THRUSTERS UP TO 4 AMPS AND NET ACCELERATION VOLTAGES SELECTABLE THROUGH THE RANGE OF 1,000 TO OVER 2,000 WITH LIFETIMES EXCEEDING 20,000 HOURS
- OPERATIONAL SIMPLICITY, ECONOMY AND HUMAN ERROR AVOIDANCE CAN BE ACHIEVED BY EXPLOITING PRESENT COMPUTER AND SENSOR TECHNOLOGIES
- MANY DESIGN TASKS WARRANT FURTHER DEFINITION. NSI BELIEVES THE TECHNOLOGY BASE IS COMPLETE. SUPPORT IN CERTAIN AREAS OFFERS GREAT POTENTIAL COST SAVINGS